AIR QUALITY IN ONTARIO 1995

Ontario

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MESSAGE FROM THE HONOURABLE NORMAN W. STERLING

MINISTER OF THE ENVIRONMENT

Protecting our air is a big challenge but we are making progress and I believe we're on the right track. Improving our air quality remains a top priority of this government. I firmly believe that all of us have the right to breathe air that is safe and clean.

This report shows that although Ontario's population grew considerably between 1971 and 1995, our air quality improved.

Progress continues to be made in the fight for cleaner air. In fact, we are one of the leaders in North America when it comes to cleaning up our air.

In October 1996, the ministry embarked on an aggressive three-year plan to update air quality standards for as many as 70 substances. Initially, we will be focussing our efforts on developing standards for 14 priority substances.

With our partners in business, government and in the community, we are taking firm action to reduce smog. Smog is a serious health and environmental problem in this province, damaging crops and forest growth and costing us billions annually. Our goal is to cut emissions of smog-causing pollutants produced in Ontario by 45 per cent by the year 2015.

Ontario's *Drive Clean* program will reduce smog-forming emissions from vehicles by about 22 per cent. Starting in 1998, we will regularly test emissions from cars, trucks and buses. Vehicles that don't pass the test will have to be repaired and retested.

As this report notes, about half the pollutants that form smog arrive in this province from the U.S. We are challenging our neighbors to do more to reduce emissions of smog-forming pollutants.

In early 1997, I met with my counterparts in 11 states and urged on them the importance of toughening their air quality regulations to deal with transboundary pollution.

We have amended a regulation to reduce emissions of volatile organic compounds from gasoline during the summer months, when the problem of smog is greatest.

Our latest initiative is the introduction of an interim standard for inhalable particulates. A major constituent of smog, these tiny particles can get into the lungs and cause respiratory problems. This new standard is an important step in our campaign to reduce the threat of smog.

I'm pleased by the progress that has been made in improving our air quality. With the support of the people of Ontario, our *Drive Clean* program and other initiatives to reduce smog will result in further improvements - and that's good news for all of us.

TABLE OF CONTENTS

TABLES

FIGURES

REPORT HIGHLIGHTS

Air quality in Ontario improved considerably between 1971 and 1995, despite a large growth in population and an increase in vehicle travel.

Levels of most major pollutants declined significantly over the 25 year period. Average levels of sulphur dioxide were reduced by 86 per cent, carbon monoxide by 87 per cent and total suspended particulates by 54 per cent. Over 22 years, nitrogen dioxide was reduced by 22 per cent and oxides of nitrogen by 46 per cent.

Between 1986 and 1995, air quality continued to improve as concentrations of nitrogen dioxide, carbon monoxide, sulphur dioxide and total reduced sulphur declined. During this period, emissions of oxides of nitrogen, carbon monoxide, sulphur dioxide, particulates and volatile organic compounds also dropped.

Regulations, control orders on major smelting operations and the Countdown Acid Rain program helped reduce sulphur dioxide emissions in the province by 81 per cent between 1971 and 1995.

Levels of total reduced sulphur decreased 47 per cent between 1985 and 1995 and 29 per cent in 1995. This reduction was due mainly to abatement and regulatory action by the Ministry of Environment and Energy.

Concentrations of 28 volatile organic compounds at 18 sites were well below existing guidelines.

Ontario's air quality index, based on readings for six major pollutants, was introduced province-wide in 1988.

In 1995, the provincial air quality index reported good to very good air quality readings 94.7 per cent of the time.

Ground-level ozone - a major component of smog - was the pollutant that exceeded the provincial air quality criterion most often. More than 50 per cent of the ozone was caused by air pollution from the U.S.

Since 1989 the ministry has increased monitoring of inhalable particulates because of health concerns.

Toronto's air during 1994 was compared with 46 cities around the world and was found to be better than many of them.

INTRODUCTION

This report summarizes the state of air quality in Ontario in 1995. It looks back to the early days of computerized data gathering and describes the growing sophistication of the province's air monitoring network. Ontario continues to benefit from one of the most comprehensive air monitoring systems in North America.

The report examines trends in levels of the major pollutants over 25 years and highlights the province's achievements in reducing pollution.

There have been some notable successes. Ministry-enforced regulations, along with policies and programs have resulted in significant reductions in many of the major pollutants, despite a large growth in population and vehicle travel in the province.

Since 1971 sulphur dioxide levels have been reduced by 86 per cent. Concentrations of carbon monoxide, total suspended particulates, nitrogen oxides and nitrogen dioxide have also greatly declined.

The air quality index, based on readings for six major pollutants, was introduced province-wide in 1988. According to the index, the air we were breathing in 1995 was good or very good for about 95 per cent of the time.

When less favorable readings were obtained, ozone was usually to blame. High levels of ozone - much of it caused by pollutants blown in from the U.S. - remain a health and environmental concern in Ontario.

Inhalable particulates also emerged as a health concern, particularly for people with respiratory problems. During the reporting period the ministry increased its monitoring of these fine particles.

Ontario's air monitoring system continues to provide us with important information about the air we breathe. With this data we can make informed decisions about what needs to be done to protect and improve our air quality.

CHAPTER 1

AMBIENT AIR MONITORING IN ONTARIO

Ambient air monitoring in Ontario measures concentrations of selected pollutants in the air of various communities across the province.

Since 1971, the Ministry of Environment and Energy has been monitoring air quality in Ontario and using this information to:

- inform the public about outdoor air quality in real time;
- provide a pollution episode warning and control mechanism for public health protection;
- assess Ontario's air quality and evaluate trends;
- identify areas where criteria are exceeded and identify the origins of pollutants;
- provide quantitative measurements to enable abatement of specific pollutant sources;
- determine the levels of pollutants from U.S. sources and their effects on Ontario; and
- provide air quality data for researchers linking environmental and human health effects to air quality.

Emissions of contaminants into the atmosphere from both human and natural activity, plus their atmospheric interactions, determine air quality.

Local air quality is influenced by motor vehicles, industrial emissions, and meteorological and topographical conditions.

For contaminants that undergo long-range transport and transformation, such as ozone, trace metals and the components of acid rain, distant sources are significant contributors to local air quality.

"THE AMBIENT AIR QUALITY MONITORING NETWORK UNDERGOES CONSTANT MAINTENANCE TO ENSURE A HIGH STANDARD OF QUALITY CONTROL."

Table 1.1 shows the relationship between monitored air pollutants and air issues.

Current Ontario ambient air quality criteria for the common pollutants considered in this report are listed in Table 1.2, along with their potential effects.

QUALITY ASSURANCE AND QUALITY CONTROL

The ministry consisted of six regions in 1995. Each had an atmospheric and terrestrial effects unit responsible for day-to-day air monitoring and maintenance.

Each day, the instruments are checked through a computerized telephone link by technicians confirming the automatic zero and span values (that is, a known value for a particular gas).

Regional technicians inspect and maintain the monitoring equipment and stations continually. If an instrument undergoes major servicing, the instrumentation and quality assurance unit will recalibrate it.

Portable calibration equipment is used by regional staff. This equipment is

TABLE 1.1 - LINKAGES BETWEEN AIR POLLUTANTS AND AIR ISSUES

ISSUE / POLLUTANT	Smog	Global Warming	Urban Air Quality	Acid Deposition	Health	Aesthetics
Ozone	YES	YES	YES	YES	YES	
Sulphur Dioxide	YES	YES	YES	YES	YES	YES
Carbon Monoxide			YES		YES	
Oxides of Nitrogen	YES	YES	YES	YES	YES	YES
VOCs	YES	YES	YES		YES	YES
Toxic Organics			YES		YES	
Particulates	YES	YES	YES	YES	YES	YES
TRS			YES		YES	YES

TABLE 1.2 - AMBIENT AIR QUALITY CRITERIA (AAQC) FOR ONTARIO

Pollutant	Type of Average	Ontario (AAQC)	Limiting Effects Based On
Sulphur Dioxide (SO_2)	1 hour 24-hour annual mean	250 ppb 100 ppb 20 ppb	Health/Vegetation
Nitrogen Dioxide (NO_2)	1-hour 24-hour	200 ppb 100 ppb	Health
Carbon Monoxide (CO)	1-hour 8-hour	30 ppm 13 ppm	Health
Ozone (O_3)	1-hour	80 ppb	Health/Vegetation
Total Suspended Particulate (TSP)	24-hour annual mean [1]	120 µg / m^3 60 µg / m^3	Visibility
Total Reduced Sulphur (TRS)	1-hour	27 ppb [2]	Odor

[1] geometric mean [2] from Kraft Pulp Mills

itself recalibrated at least twice a year.

There are other monitoring programs, such as those operated by the Lambton Industrial Society, Environment Canada and Ontario Hydro, which the ministry either audits or conducts comparisons with. It also uses data from these services to judge provincial air quality.

The environmental monitoring and reporting branch operates a laboratory with gas reference standards that adhere to the U.S. National Institute of Standards and Technology (NIST) as well as the pollution measurement division of Environment Canada.

Performance audits are conducted on the sulphur dioxide, nitrogen oxides/nitrogen dioxide, ozone and total reduced sulphur (as hydrogen sulphide) monitors approximately three times per year and on carbon monoxide monitors once per year.

Chemical analyses performed by the laboratory services branch are subject to quality assurance and control.

The ambient air quality monitoring network undergoes constant maintenance to ensure a high standard of quality control.

Continuous real-time and particulate air quality data are reviewed, assessed and validated constantly by regional staff and the environmental monitoring and reporting branch.

Action is taken immediately to correct anything that may affect validity of data.

These measures ensure that ambient air monitoring data are valid, complete, comparable, representative and accurate.

Continuous air monitoring instruments were given 713 performance audits in 1995. Eighty-four per cent of the audits were found to be within the acceptable performance criterion, i.e. measured values were within 10 per cent of the standard value. For the remaining 16 per cent which fell outside the 10 per cent range, station log records and backup charts were consulted to adjust data to reflect true ambient concentrations. As a result, the network for 1995 had 94.1 per cent valid data out of approximately four million data points.

AIR QUALITY DATA BASE

The ambient air quality data used in this report are stored in the ministry's air quality information system (AQUIS). Approximately four million air pollution measurements are added to AQUIS yearly with the vast majority representing Ontario's more heavily populated urban areas.

A statistical pattern test is used to identify data anomalies, such as unusual pollutant concentrations. Each pollutant has a predetermined pollutant concentration range based on historical data. Values outside this range are flagged.

AQUIS data are divided into two major groupings: continuous (one-hour) measurements and daily (24-hour) measurements.

Hourly data are obtained from automated ambient air monitoring instruments which operate continuously. These produce an averaged measurement each hour for a possible 8,760 measurements in a year.

SO_2, CO, O_3, NO_x and TRS compounds are all measured hourly. A valid annual mean requires at least 5,840 hourly readings or 67 per cent valid data. Typically the network yields approximately 95 per cent valid data.

The instruments which provide daily measurements from a 24-hour sampling period are usually operated on one, three or six-day cycles. They measure TSP, PM_{10}, lead, various trace metals, sulphate and nitrate.

For daily data, a valid annual mean requires at least two-thirds of possible samples, i.e. a station operating a six-day sampling cycle would require at least 40 out of a possible 61 samples.

To be included in the 10-year trend analysis, a site must have valid annual means for at least eight out of the 10 years from 1986 to 1995. To be included in long-term analysis a site must have a valid mean for at least 20 out of 25 years.

CHAPTER 2

TRENDS IN AIR QUALITY AND EMISSIONS

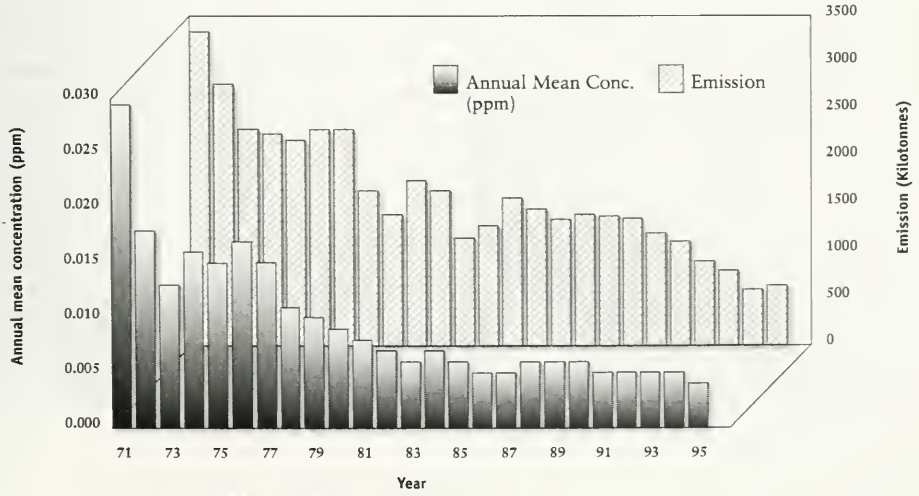
Air pollution comes from many different sources: stationary, such as factories, power plants and smelters; mobile, such as motor vehicles, aircraft and trains; and natural, such as forest fires and windblown dust. All contribute to air pollution in Ontario. Air pollution can be generated both locally and regionally and transported over long distances, from country to country.

Each year the ministry gathers and analyses air quality concentration data from monitoring sites across Ontario. Trends are derived by averaging direct measurements. Over the past 25 years significant reductions have been achieved in ambient provincial pollution levels.

Ministry programs and policies have led the way to these significant reductions. One of the best examples is the 25-year sulphur dioxide (SO_2) trend, **Figure 2.1**. Sulphur

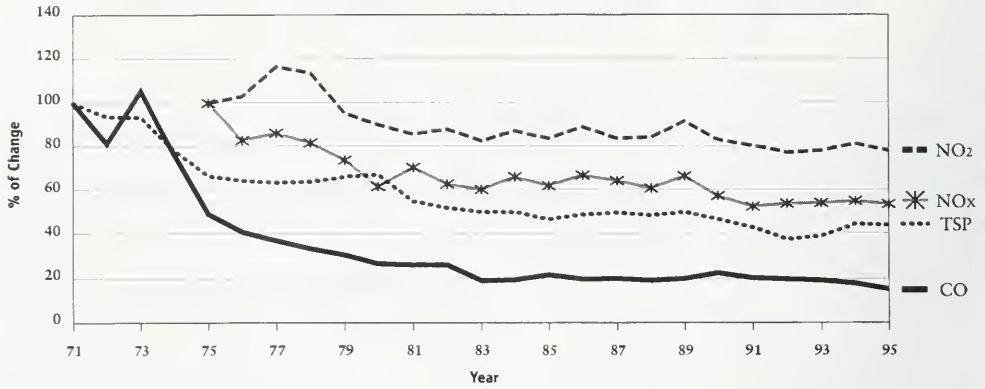
"Ontario Regulations 346 and 350, control orders on major smelting operations and the Countdown Acid Rain program have helped reduce SO_2 emissions in the province by 81 per cent since 1971."

FIGURE 2.1
LONG-TERM TREND FOR SULPHUR DIOXIDE (1971-1995)



Note: 12 sites operated over 25 years
Ontario Annual AAQC = 0.020 ppm

FIGURE 2.2
TREND IN CRITERIA AIR POLLUTANTS



NOx and NO2 data from 15 sites beginning in 1975
CO and TSP data from 9 sites

dioxide is emitted primarily by burning fossil fuels containing sulphur, smelting operations, and pulp and paper processes in Ontario.

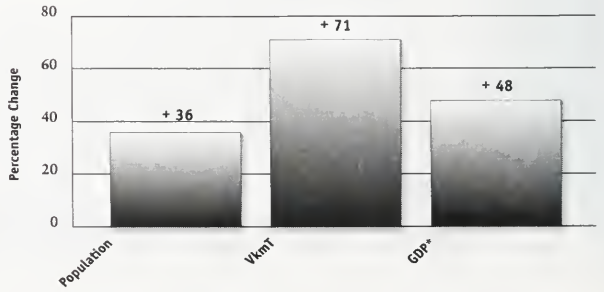
Ontario Regulations 346 and 350, control orders on major smelting operations and the Countdown Acid Rain program have helped reduce SO_2 emissions in the province by 81 per cent since 1971. A similar decrease in ambient SO_2 (86 per cent) has been recorded over the same 25-year period.

Other examples of air quality improvement: carbon monoxide levels decreased 87 per cent and total suspended particulates 54 per cent over the past 25 years; nitrogen dioxide levels decreased 22 per cent and oxides of nitrogen 46 per cent over the past 21 years, **Figure 2.2.** These reductions occurred during significant population and economic growth in Ontario. Since 1971, the provincial population increased 36 per cent and vehicle-kilometres travelled were up 71 per cent. Gross provincial domestic product has risen 48 per cent since 1981, **Figure 2.3.**

Ground-level ozone (O_3), however, remains a concern in Ontario, especially in the Windsor-to-Cornwall corridor. Not only does ozone continue to exceed the provincial one-hour AAQC, but the ozone annual means since 1987 are greater than the annual means recorded from 1979 to 1987, **Figure 2.4.**

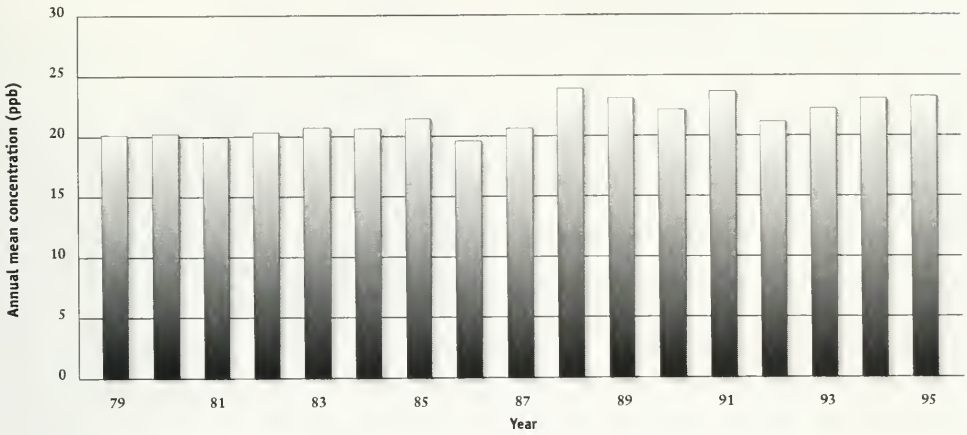
Occurrences of ozone exceeding the criterion, and/or the number of such occurrences covering wide areas, tend

FIGURE 2.3
ONTARIO'S POPULATION, VEHICLE-KILOMETRES TRAVELLED (VkmT) AND GROSS DOMESTIC PRODUCT (GDP*) (1971-1995)



Source: Population and GDP - Statistics Canada; VkmT - Environment Canada
*GDP-percentage increase (1981-1995)

FIGURE 2.4
LONG-TERM TREND FOR OZONE (1979-1995)



Note: 23 sites operated over 17 years

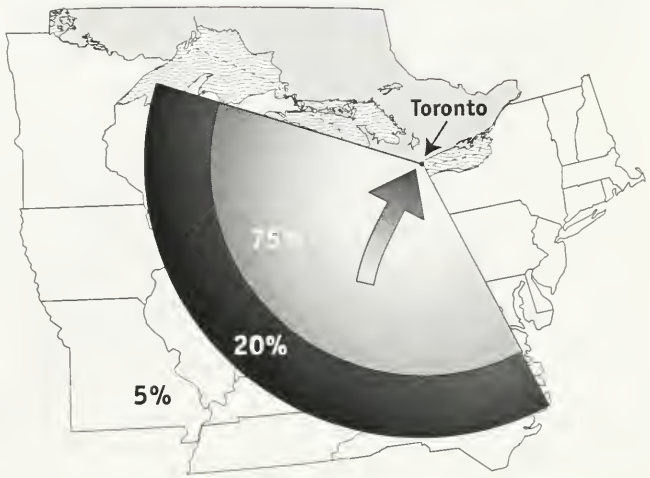
to vary substantially year to year because of weather.

Significant amounts of ozone and its precursors are carried into Ontario from the United States. During hot summer days, which favor ozone, it is estimated that more than half the province's ground-level ozone can be attributed to transboundary pollution.

Figure 2.5 shows the area from which southern Ontario air arrives during days of widespread elevated levels of O_3. Whenever high ozone was recorded, the air mass had previously resided over the high emission areas of the states south or west of Ontario.

Inhalable particulates (PM_{10}) and respirable particulates ($PM_{2.5}$) are also of emerging concern in Ontario. PM_{10} monitoring began in Ontario in 1989. It is discussed in Chapter 3.

FIGURE 2.5
U.S. SOURCES OF TRANSBOUNDARY OZONE



CHAPTER 3

PRINCIPAL CONTAMINANTS

Pollutants NO_2, CO, O_3, SO_2, TSP, PM_{10} and TRS are discussed in this chapter, including their characteristics, sources, effects, 1995 results and trends. Ambient air quality data presented in this chapter are based on direct measurement. Corresponding annual emission trends are taken from the Ontario emission inventory system (OEIS). Emission estimates for these pollutants are based on best available information.

"PROVINCIAL TRS (TOTAL REDUCED SULPHUR) LEVELS DECREASED 47 PER CENT DURING THE 10-YEAR PERIOD AND 29 PER CENT IN THE FINAL YEAR. THIS IS MAINLY ATTRIBUTABLE TO ABATEMENT AND REGULATORY ACTION BY THE MINISTRY."

NO_2 NITROGEN DIOXIDE

TRENDS IN AMBIENT AIR CONCENTRATIONS

1986-95: .....14 PER CENT DECREASE

1994-95: .....5 PER CENT DECREASE

TRENDS IN AIR EMISSION ESTIMATES: NITROGEN OXIDES (NO_x)

1986-95: .....24 PER CENT DECREASE

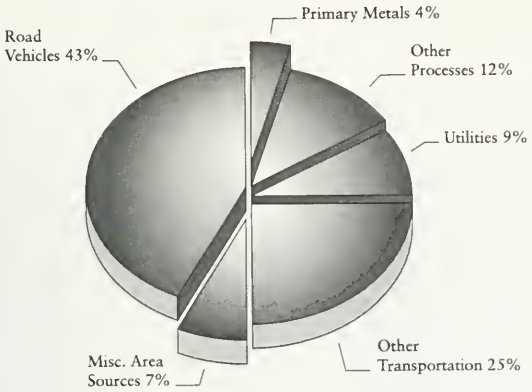
1994-95: .....4 PER CENT DECREASE

ONTARIO AMBIENT AIR QUALITY CRITERIA (AAQC)

1-HOUR: .....200 PARTS PER BILLION (ppb)

24-HOUR: .....100 ppb

FIGURE 3.1
ONTARIO NITROGEN OXIDES EMISSIONS BY SECTORS (EMISSIONS FROM HUMAN ACTIVITY, 1995 ESTIMATES)

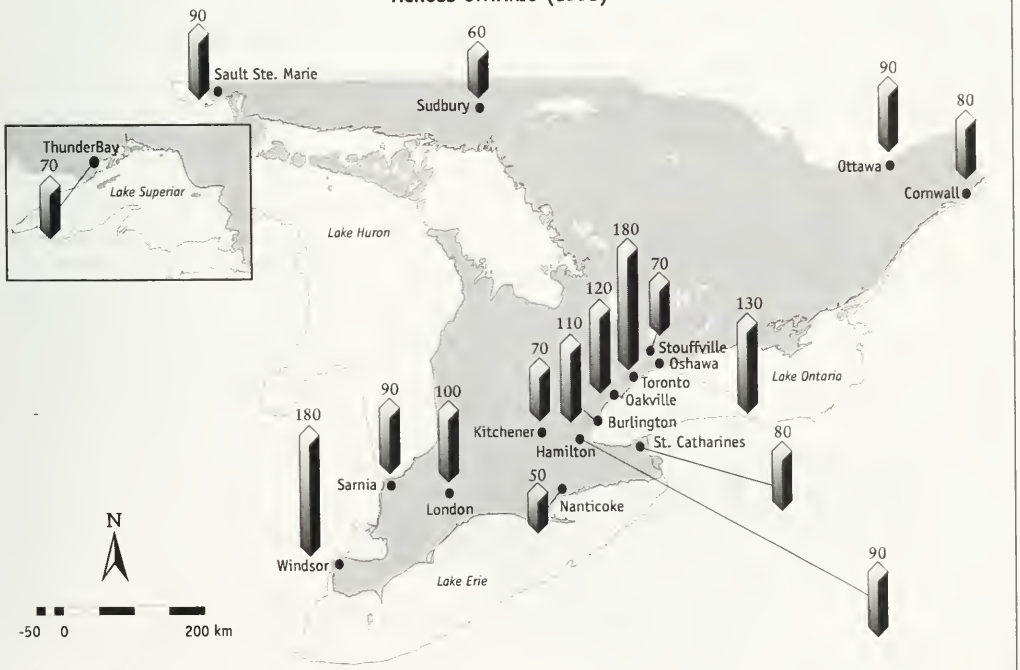


NITROGEN DIOXIDE (NO_2): Nitrogen dioxide is a reddish brown gas with a pungent and irritating odor. It is one of the oxides of nitrogen (NO_x).

NO_2 is a strong oxidizing agent that reacts in air to form corrosive nitric acid and toxic organic nitrates. It also plays a major role in atmospheric reactions that produce ground-level ozone, a major component of smog.

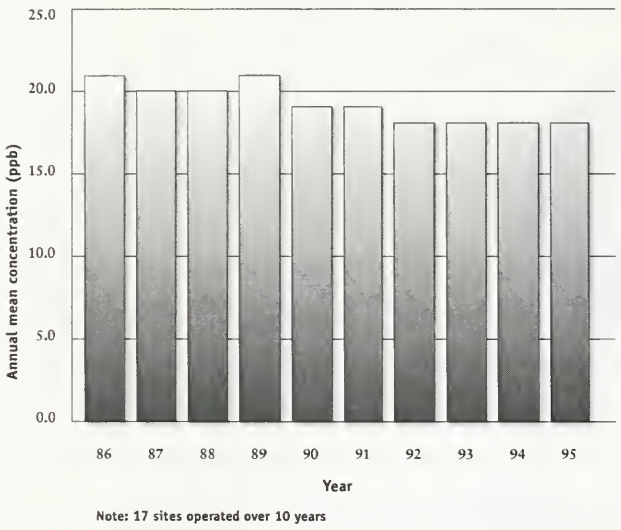
EFFECTS: Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infection. Sensitivity increases for people with asthma and bronchitis. NO_2 chemically transforms into dilute nitric acid and, when deposited, contributes to lake acidification. NO_2 can corrode metals, fade fabrics and degrade rubber. It can damage trees and crops, resulting in substantial losses.

FIGURE 3.2
GEOGRAPHICAL DISTRIBUTION OF ONE-HOUR MAXIMUM NO_2 CONCENTRATIONS (ppb) ACROSS ONTARIO (1995)



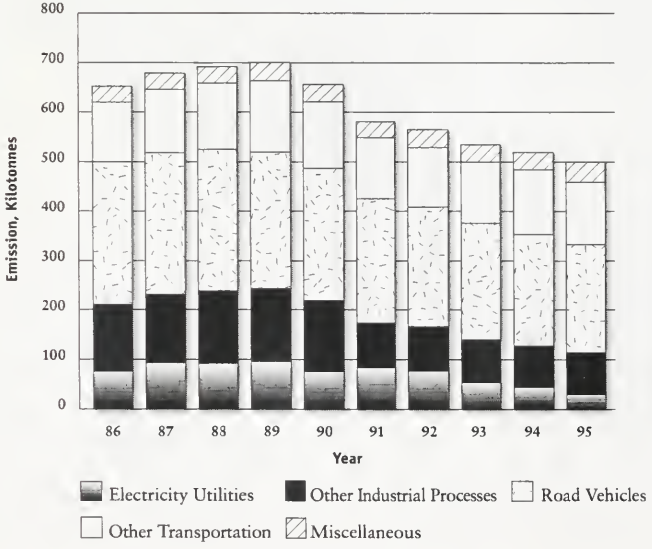
Note: 1-h Ontario AAQC = 200 ppb

FIGURE 3.3
10-YEAR TREND FOR NO_2



Note: 17 sites operated over 10 years

FIGURE 3.4
TREND FOR ONTARIO NITROGEN OXIDES EMISSION ESTIMATES (1986-1995)



SOURCES: All combustion in air produces oxides of nitrogen. Approximately 68 per cent of NO_x comes from the transportation sector, **Figure 3.1.** A large part of the remaining 32 per cent comes from power generation, primary metal production and incineration. Natural sources of NO_x include lightning and the aerobic activity of soil bacteria. These natural sources, however, are small compared to emissions caused by human activity.

RESULTS FOR 1995: NO_2 was monitored at 28 locations in 1995. There were no observations above the one-hour or 24-hour AAQC in 1995. Typically, highest NO_2 levels are recorded in larger urban centres, **Figure 3.2.** The highest annual mean (30 ppb) was measured in downtown Toronto, south Etobicoke and York, all in the metropolitan Toronto area. The maximum one-hour value (180 ppb) was recorded at both the University Avenue site in Windsor and the York site. The maximum 24-hour value (100 ppb) was recorded at the York monitoring site.

TRENDS: Provincial average NO_2 concentrations remained relatively constant throughout the latter half of the 1980s, followed by a decreasing trend in the 1990s, **Figure 3.3.** Average NO_2 concentrations in 1995 were 14 per cent lower than the levels recorded in 1986. Provincial NO_x emissions decreased 24 per cent since 1986, **Figure 3.4.** The decreasing trend is largely due to reductions in emissions in the transportation and industrial sectors.

CO CARBON MONOXIDE

TRENDS IN AMBIENT AIR CONCENTRATIONS

1986-95: .....36 PER CENT DECREASE

1994-95: .....27 PER CENT DECREASE

TRENDS IN AIR EMISSION ESTIMATES

1986-95: .....17 PER CENT DECREASE

1994-95: .....1 PER CENT INCREASE

ONTARIO AMBIENT AIR QUALITY CRITERIA (AAQC)

1-HOUR: .....30 PARTS PER MILLION (ppm)

8-HOUR: .....13 ppm

CARBON MONOXIDE (CO): A colorless, odorless, tasteless and poisonous gas produced primarily by incomplete burning of fossil fuels.

SOURCES: The transportation sector accounts for 67 per cent of all CO emissions from human activity, Figure 3.5. A large part of the remaining 33 per cent comes from primary metal producers (20 per cent) and from fuel combustion in space heating and industrial processes (seven per cent).

EFFECTS: Carbon monoxide enters the bloodstream and reduces oxygen delivery to organs and tissues. Exposure to high levels is linked with impaired vision, work capacity, learning ability and performance of difficult tasks.

RESULTS FOR 1995: Carbon monoxide was measured at 21 sites

FIGURE 3.5
ONTARIO CARBON MONOXIDE EMISSIONS BY SECTORS (EMISSIONS FROM HUMAN ACTIVITY, 1995 ESTIMATES)

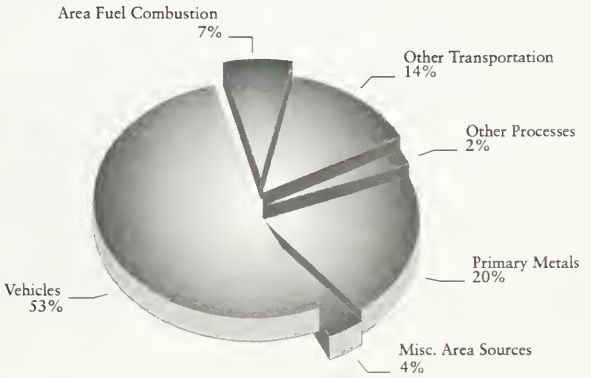
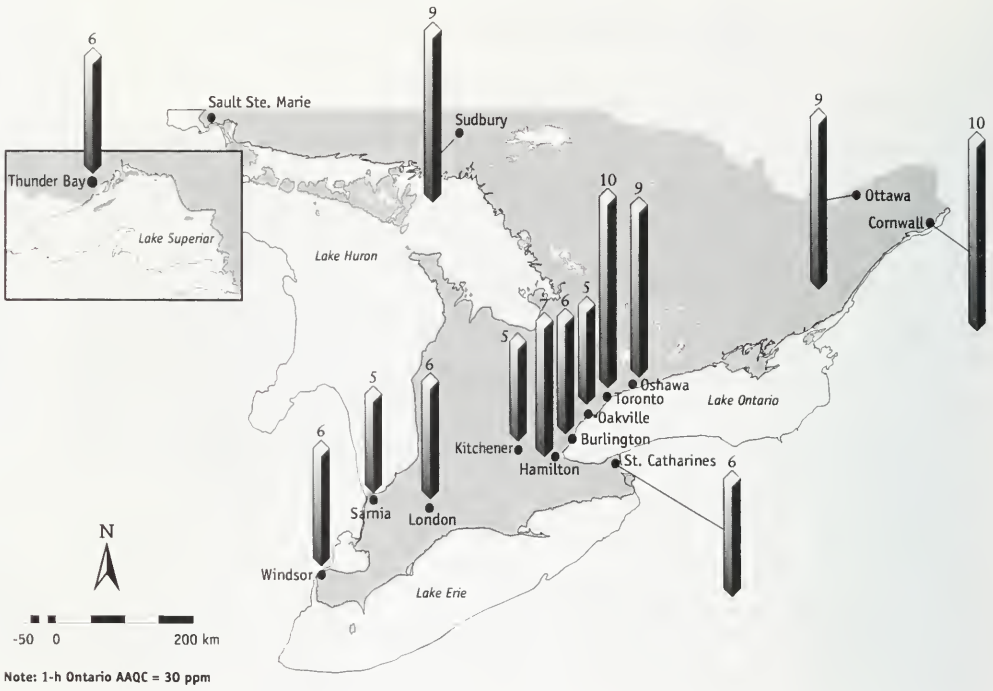


FIGURE 3.6
GEOGRAPHICAL DISTRIBUTION OF ONE-HOUR MAXIMUM CO CONCENTRATIONS (ppm) ACROSS ONTARIO (1995)



in 1995. Highest CO levels are recorded typically in larger urban centres as a result of vehicle emissions, Figure 3.6. The highest annual mean (1ppm) was recorded at the York and Scarborough sites in Metropolitan Toronto. There were no recordings above the one-hour or eight-hour AAQC in 1995.

TRENDS: The 10-year trend in measured concentrations and emissions of carbon monoxide are shown in Figures 3.7 and 3.8. Improvement continued from 1986 to 1995 with a 36 per cent decrease in carbon monoxide levels and 17 per cent reduction in total emissions. There were no recordings above the one-

FIGURE 3.7
10-YEAR TREND FOR CO

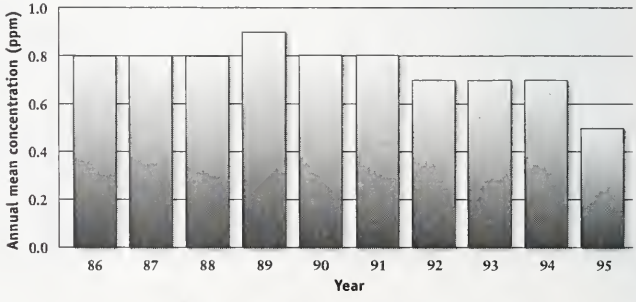
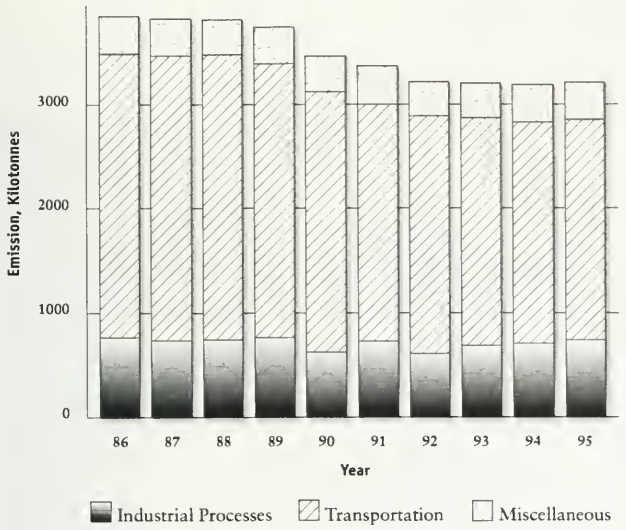
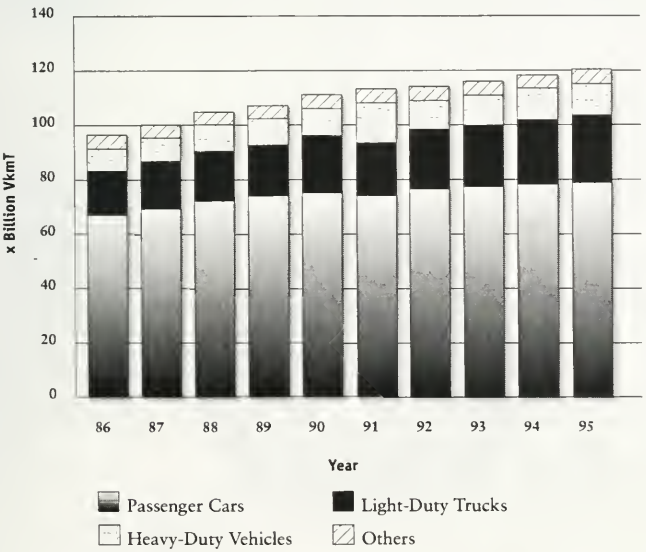


FIGURE 3.8
TREND FOR ONTARIO CARBON MONOXIDE EMISSION ESTIMATES (1986-1995)



hour or eight-hour CO criteria after 1991, despite the 25 per cent increase in Ontario vehicle kilometres travelled during the same period, **Figure 3.9.** These trends may reflect the superior fuel economy of today's electronically controlled vehicles.

FIGURE 3.9
ONTARIO VEHICLE-KILOMETRES TRAVELLED (1986-1995)



O_3 GROUND-LEVEL OZONE

TRENDS IN AMBIENT AIR CONCENTRATIONS

1986-95: .....NO DISCERNIBLE TREND

1994-95: .....NO CHANGE

TRENDS IN PRECURSOR EMISSION ESTIMATES OF NITROGEN OXIDES (NO_x) AND VOLATILE ORGANIC COMPOUNDS (VOCs)

1986-95: .....24 PER CENT DECREASE IN NO_x

..... 5 PER CENT DECREASE IN VOCs

1994-95: ..... 4 PER CENT DECREASE IN NO_x

NO CHANGE IN VOCs

ONTARIO AMBIENT AIR QUALITY CRITERION (AAQC)

1-HOUR: .....80 PARTS PER BILLION (ppb)

GROUND LEVEL OZONE (O_3): A colorless, odorless gas at ambient concentrations, ozone is a major component of summer smog.

SOURCES: Ground-level ozone is not emitted in large amounts directly into the atmosphere. It results from chemical reactions between NO_x and volatile organic compounds (VOCs) in the presence of sunlight. High levels typically occur from May to September, between noon and early evening. **Figure 3.10** shows estimates of Ontario's VOC emissions caused by human activity, by sector. Road vehicles and other transportation modes account for approximately 28 per cent of VOC emissions. Owing to a large forested area in the province, biogenic emissions

FIGURE 3.10
ONTARIO VOC EMISSIONS BY SECTORS
(EMISSIONS FROM HUMAN ACTIVITY, 1995 ESTIMATES)

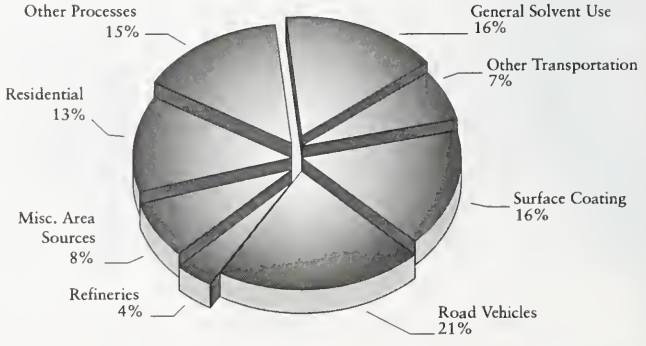
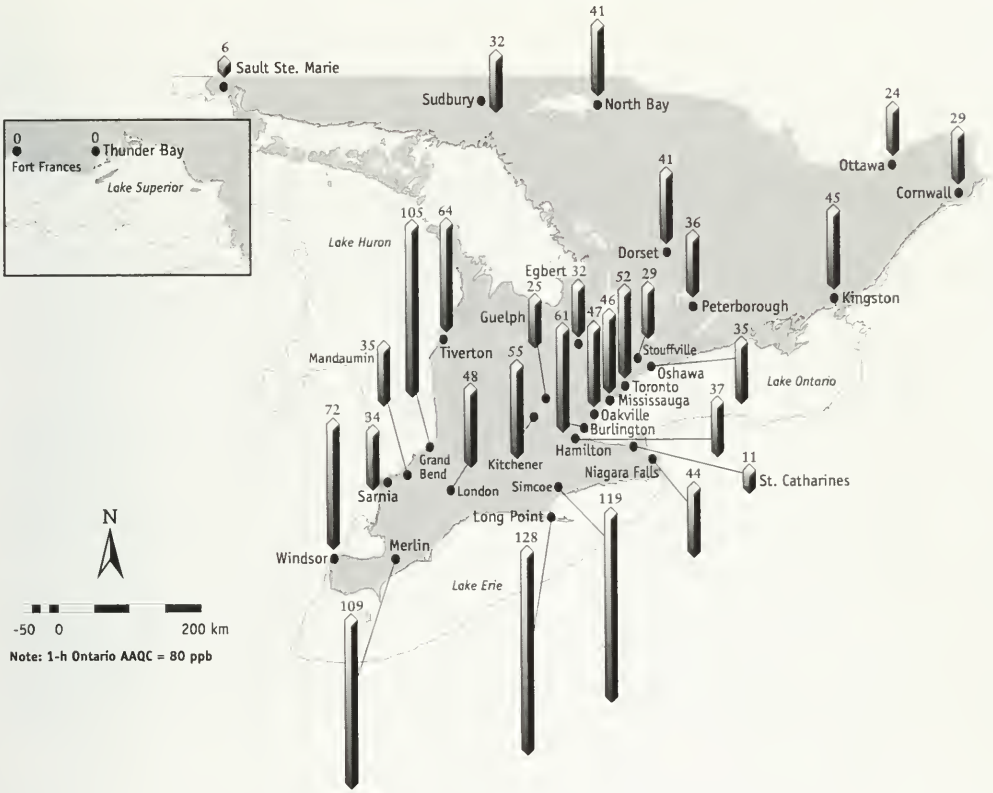


FIGURE 3.11
GEOGRAPHICAL DISTRIBUTION OF ONE-HOUR OZONE CONCENTRATION > 80 ppb ACROSS ONTARIO (1995)



of certain VOCs in Ontario are significant, approximately three times those from sources caused by human activity.

EFFECTS: Ground-level ozone irritates the respiratory tract and eyes. Exposure to high levels of O_3 results in chest tightness, coughing and wheezing. People with respiratory and heart problems are at higher risk. Ozone causes agricultural crop loss each year in Ontario and noticeable leaf damage in many crops, garden plants and trees.

RESULTS FOR 1995: Ground-level ozone is the pollutant which exceeded the provincial air quality criterion most often. In 1995, the Ontario

FIGURE 3.12
10-YEAR TREND FOR OZONE

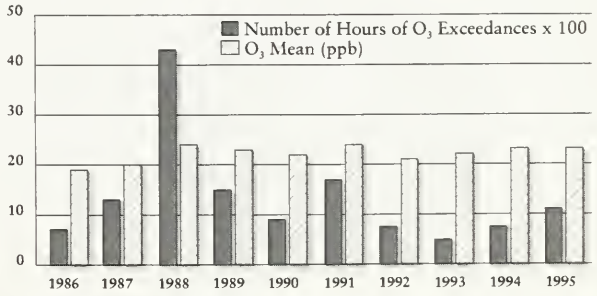
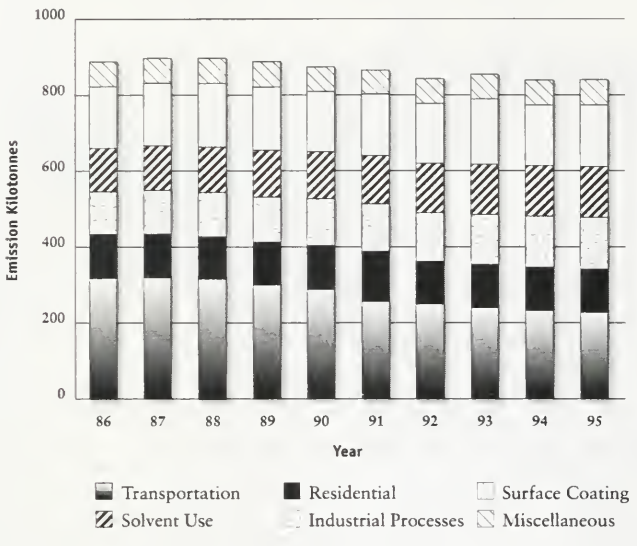


FIGURE 3.13
TREND FOR ONTARIO VOC EMISSION ESTIMATES (1986-1995)



one-hour ozone criterion was exceeded at 41 of 45 monitoring stations. All ozone monitoring sites in southern Ontario recorded at least one hour of elevated ozone (above 80 ppb) in 1995. At these levels, people with heart and lung problems are at risk. People with sensitivities may have trouble breathing and their health may be damaged if they engage in vigorous exercise. **Figure 3.11** shows geographical distribution of the number of hours of elevated ozone across Ontario. Long Point, a rural site on the north shore of Lake Erie, recorded the greatest number (128) while Grand Bend and Tiverton on the east shore of Lake Huron recorded the maximum one-hour (157 ppb) and maximum annual mean (31.6 ppb) concentrations respectively in 1995.

Among urban sites, Windsor recorded the greatest number of instances of elevated ozone (72). The highest one-hour urban concentration (140 ppb) was measured at London and the highest urban annual mean (29.7 ppb) recorded at Sudbury. Urban locations, because of the scavenging of ozone by nitric oxide and other pollutants, record lower annual levels of ozone than rural locations. Year-to-year ozone levels are strongly influenced by weather.

More than 50 per cent of provincial ozone levels are due to the long-range transport of ozone and its precursors from neighboring U.S. states. The seriousness of transboundary flow is reflected in the relatively higher levels occurring at the northern shore of Lake Erie, eastern shore of Lake Huron and urban sites such as Windsor.

Trends: Interpretation of the 10-year ozone trends is complicated by meteorological factors and emission changes. Just as the highest number of one-hour elevated levels of ozone (4345) in 1988 are likely attributable in part to weather, so probably the low numbers in 1993 reflect conditions less conducive to production of ground-level ozone. The trend of the composite annual means for the 10-year period (1986-1995) is shown in **Figure 3.12**. There is no discernible trend in mean ozone levels over the past 10 years. The composite annual mean (23.2 ppb) in 1995 was the third highest reported for the 10-year period. However, elevated levels of ozone have been increasing since 1992. Weather conditions in 1995 led to elevated ozone concentrations. As a result of new vehicle emission standards, VOC emissions from the transportation sector showed a slight decrease from 1989 to 1995. However, there was a slight increase in the use of solvents and surface coating over the same period. Overall, there was a five per cent decrease in VOC emissions from 1986 to 1995, **Figure 3.13**.

The introduction of lower gasoline volatility (82.8 kPa to 72.0 kPa) for the summer months, beginning in 1989, resulted in a further reduction in VOC emissions. It is estimated that lowering the gasoline volatility during the summer months reduced provincial VOC emissions by 1.1 per cent in 1995.

SO_2 SULPHUR DIOXIDE

TRENDS IN AMBIENT AIR LEVELS

1986-95: .....25 PER CENT DECREASE

1994-95: .....25 PER CENT DECREASE

TRENDS IN PRECURSOR EMISSION ESTIMATES

1986-95: .....52 PER CENT DECREASE

1994-95: .....7 PER CENT INCREASE

ONTARIO AMBIENT AIR QUALITY CRITERIA (AAQC)

1-HOUR: .....250 PARTS PER BILLION (ppb)

24-HOUR: .....100 ppb

1 YEAR: .....20 ppb

SULPHUR DIOXIDE (SO_2): Sulphur dioxide is a colorless gas. It smells like burnt matches. It can be oxidized to sulphur trioxide (SO_3), which in the presence of water vapor is readily transformed to sulphuric acid mist. Sulphur dioxide can be oxidized to form acid aerosols.

SOURCES: Approximately 55 per cent of the SO_2 emitted in Ontario in 1995 came from four sources regulated under the Countdown Acid Rain program: INCO, Falconbridge, Algoma Steel-Wawa and Ontario Hydro. Other industrial sources include iron and steel mills, petroleum refineries and pulp and paper mills. Small sources include residential, commercial and industrial space heating, **Figure 3.14.**

EFFECTS: Health effects caused by

FIGURE 3.14
ONTARIO SULPHUR DIOXIDE EMISSIONS BY SECTORS (EMISSIONS FROM HUMAN ACTIVITY, 1995 ESTIMATES)

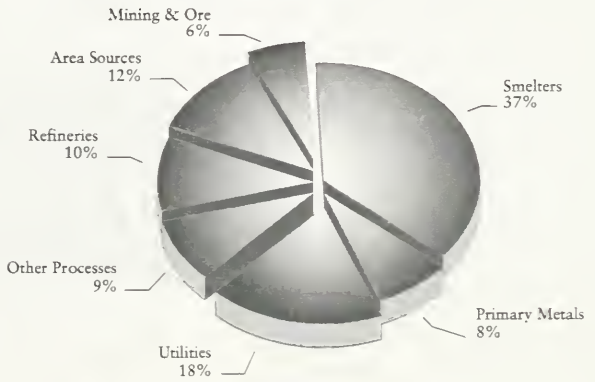
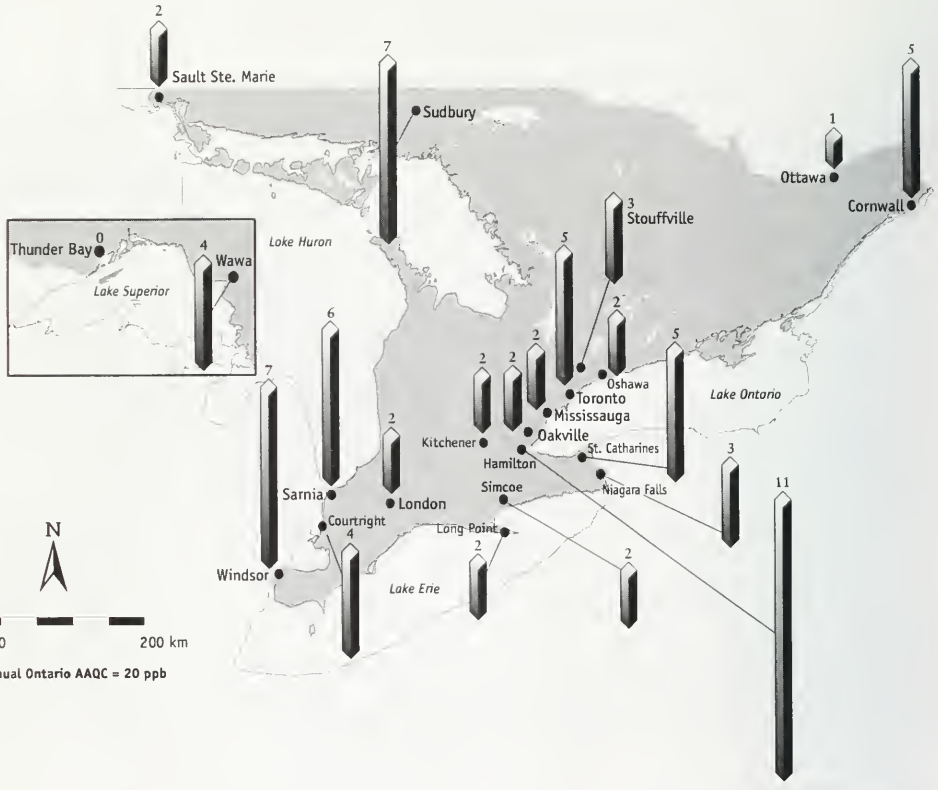
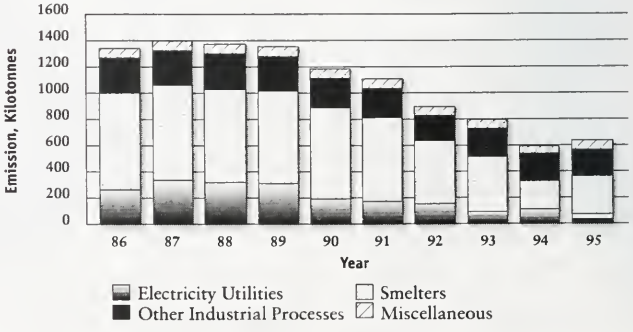


FIGURE 3.15
ANNUAL MEAN SO_2 CONCENTRATIONS (ppb) ACROSS ONTARIO (1995)



exposure to high levels of sulphur dioxide include breathing problems, respiratory illness, changes in the lung's defences and worsening respiratory and cardiovascular disease. People with asthma or chronic lung or heart disease are the most sensitive to SO_2. It also damages trees and crops. Sulphur dioxide, along with oxides of nitrogen, are the main precursors of acid rain. This contributes to the acidification of lakes and streams, accelerated corrosion of buildings and reduced visibility. Sulphur dioxide also causes formation of microscopic acid aerosols which have serious health implications, as well as contributing to climate change.

FIGURE 3.16
TREND FOR ONTARIO SULPHUR DIOXIDE EMISSION ESTIMATES (1986-1995)

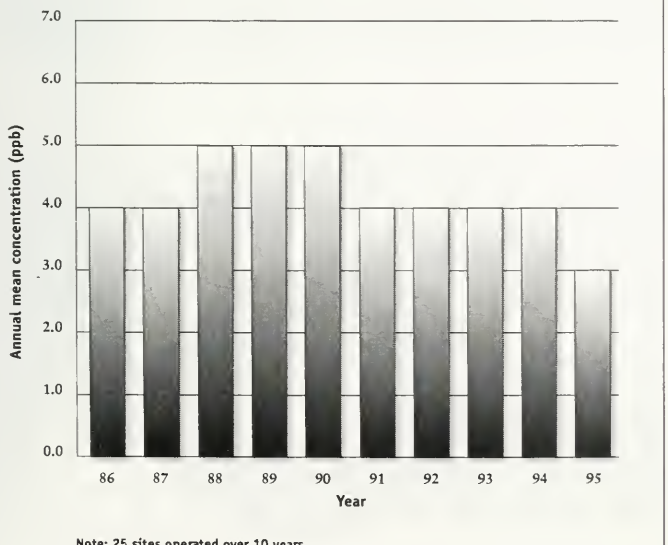


RESULTS FOR 1995: The highest annual mean SO_2 (11 ppb) was recorded in Hamilton, downwind of the largest steel maker in Ontario. The greatest number of instances (30) when the one-hour AAQC was exceeded were observed at Copper Cliff in Sudbury. The highest one-hour concentration (1040 ppb) was also observed in Sudbury. At this level there may be damage to vegetation but no health effects. Thirteen of the province's 52 SO_2 monitoring sites recorded at least one instance of exceeding the one-hour criterion in 1995. Of these 13 stations, 12 are in the Sudbury basin and one in Wawa. Two instances of exceeding the 24-hour criterion (100 ppb) in 1995 were recorded at Copper Cliff in Sudbury. **Figure 3.15** shows the annual SO_2 concentrations across Ontario. Centres with major emission sources such as Hamilton, Windsor and Sudbury recorded the highest annual levels. The annual AAQC for SO_2 was not exceeded in 1995.

TRENDS: Ontario's SO_2 emissions decreased by 52 per cent between 1986 and 1995, while average SO_2 air quality in the province improved by about 25 per cent, **Figures 3.16** and **3.17.** Regulation 346 and 350, control orders on smelting operations and the Countdown Acid Rain program have resulted in reduced emissions. Note that total SO_2 emissions in 1995 were 636 kilotonnes, well below the 1994 Countdown limit of 885 kilotonnes.

SO_2 emissions, local ambient SO_2 concentrations and deposition of sulphur compounds in rain and snow contribute to the acidification of Ontario's lakes and streams. The downward trend in Ontario SO_2 emissions, plus SO_2 emission reductions in the U.S. implemented in 1995, are helping to meet the deposition target of 20 kg/ha/yr of wet sulphate. This threshold protects all but the most acid-sensitive lakes.

FIGURE 3.17
10-YEAR TREND FOR SULPHUR DIOXIDE



Note: 25 sites operated over 10 years

TSP TOTAL SUSPENDED PARTICULATES

TRENDS IN AMBIENT AIR CONCENTRATIONS

1986-95: .....2 PER CENT INCREASE

1994-95: .....5 PER CENT INCREASE

TRENDS IN AIR EMISSION ESTIMATES
(DUE TO HUMAN ACTIVITY)

1986-95: .....22 PER CENT DECREASE

1994-95: .....1 PER CENT INCREASE

ONTARIO AMBIENT AIR QUALITY CRITERIA (AAQC)

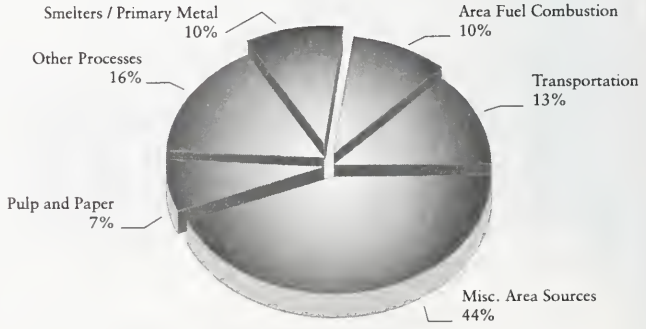
24-HOUR: .....120 MICROGRAMS PER CUBIC METRE ($\mu g/m^3$)

1 YEAR: .....60 $\mu g/m^3$

TOTAL SUSPENDED PARTICULATES (TSP): Total suspended particulates include aerosols, smoke, fumes, dust, fly ash and pollen. Composition varies with place and season, but normally includes soil particulates, organic matter, sulphur and nitrogen compounds and metals. Size range varies from 0.1 to 100 microns.

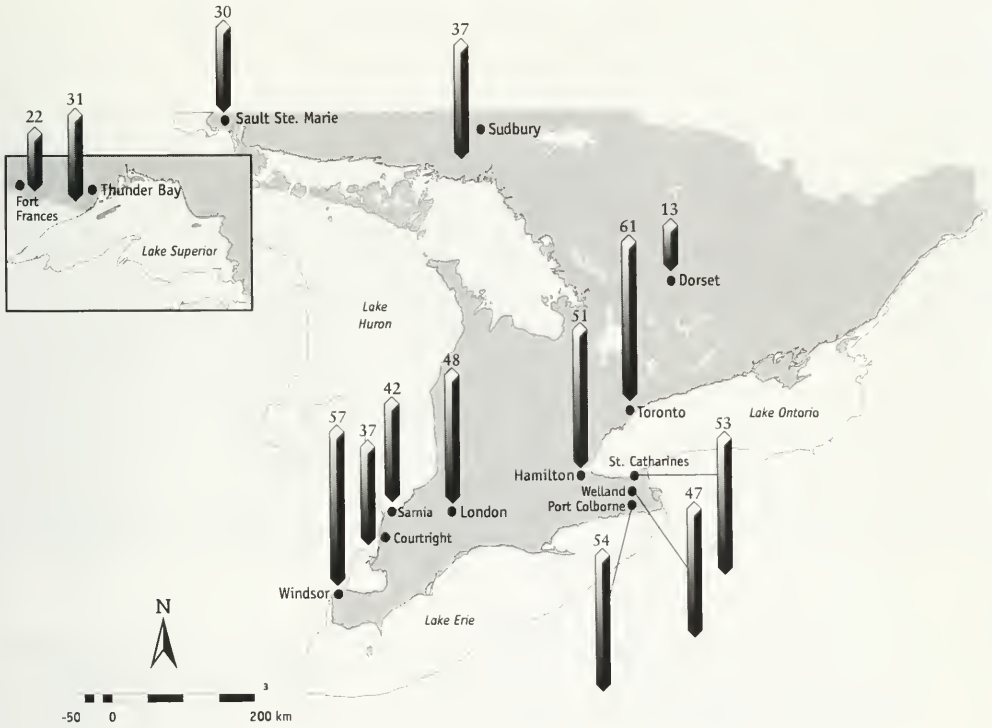
SOURCES: Particulate matter is emitted from industrial processes such as fuel combustion, incineration, construction, mining, metal smelting and processing. In the urban airshed, motor vehicle exhaust, residential wood combustion and road dust are major sources, **Figure 3.18.** Natural sources include wind-blown soil, forest fires, ocean spray and volcanic activity.

FIGURE 3.18
ONTARIO PARTICULATE EMISSIONS BY SECTORS
(EMISSIONS FROM HUMAN ACTIVITY, 1995 ESTIMATES)



*Emissions from road dust, construction, agriculture, etc. are not included.

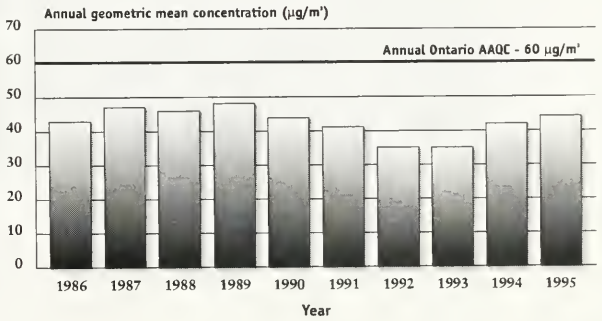
FIGURE 3.19
ANNUAL MEAN TOTAL SUSPENDED PARTICULATES CONCENTRATIONS (µg/m³) ACROSS ONTARIO (1995)



EFFECTS: The greatest effect on health is from particles 10 microns or less in diameter (PM_{10}), which can aggravate bronchitis, asthma and other respiratory diseases. These small particles have been linked to increased hospital admissions and premature death. Corrosion, soiling, damage to vegetation and visibility reduction are additional effects.

RESULTS FOR 1995: TSP monitoring was conducted at 87 locations in 1995. Since 1989, the ministry has increased monitoring for the smaller fraction (less than 10 microns) of the particulate because it is more of a health concern, and furthermore, it is believed to travel great distances.

FIGURE 3.20
10-YEAR TREND FOR TSP

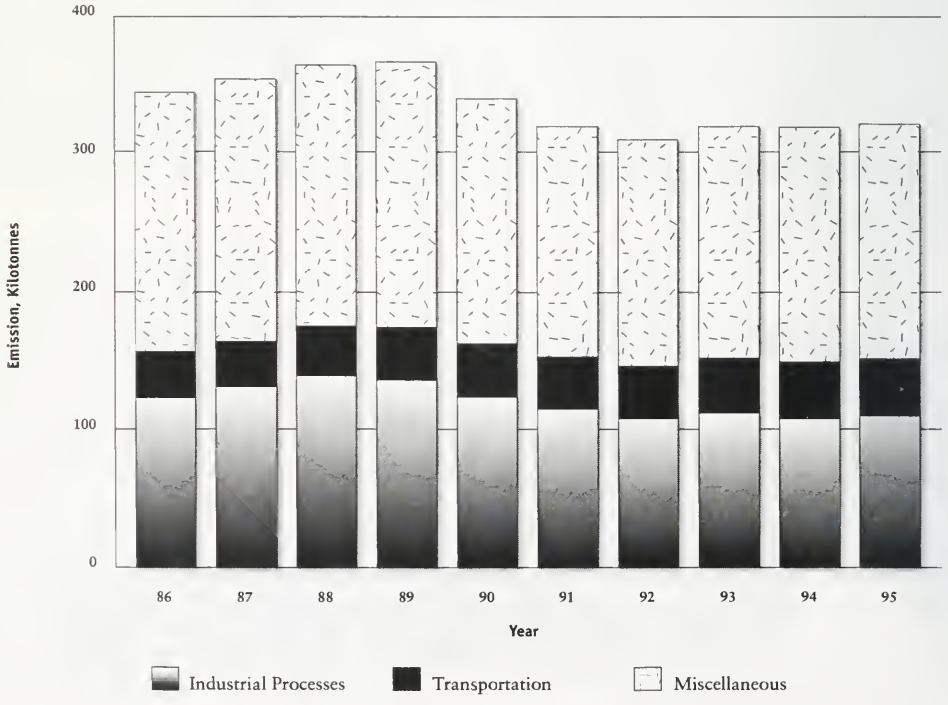


The lowest TSP levels in the province were measured at Dorset where the annual geometric mean was 13 µg/m³. The highest annual geometric mean (97 µg/m³) was measured near a scrap metal operation in Windsor. The maximum 24-hour reading (579 µg/m³) was measured near a lead smelting operation in Mississauga. Fifty-seven stations (66 per cent) exceeded the 24-hour AAQC and 22 (25 per cent) exceeded the annual criterion. At levels above 120 µg/m³, visibility is affected. The spatial distribution of annual TSP levels is shown in **Figure 3.19** for selected monitoring sites across the province.

TRENDS: The trend in annual mean TSP concentrations at 16 sites with a 10-year record is shown in **Figure 3.20**. Particulate levels over the 10-year period (1986 to 1995) show no significant trend. There were decreases from 1989 to 1993 but between 1993 and 1995 TSP levels increased slightly.

Particulate emissions from selected major sectors, including transportation, utilities and major industrial processes, showed a slight upward trend from 1986 to 1989, downward from 1990 to 1992 and generally constant over the last three years, **Figure 3.21**. Fugitive sources such as road dust, construction and surface erosion are not included, neither are particulate emissions from forest fires, which can vary from year to year and can be several times those of human activity.

FIGURE 3.21
TREND FOR ONTARIO PARTICULATE EMISSION ESTIMATES (1986-1995)



PM_{10} INHALABLE PARTICULATES

TRENDS IN AMBIENT AIR CONCENTRATIONS

1991-95: .....NO DISCERNIBLE TREND

1994-95: .....15 PER CENT DECREASE

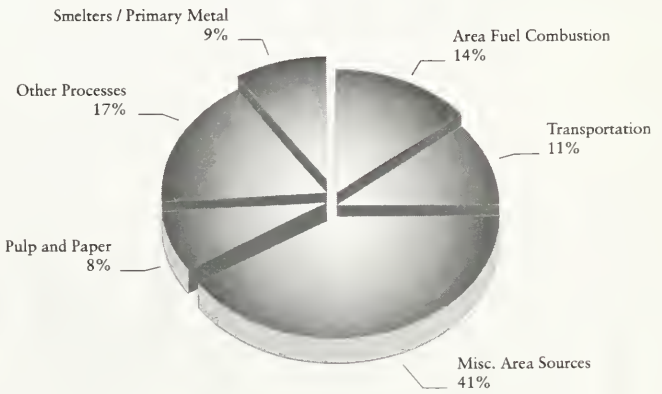
ONTARIO 24-HOUR INTERIM AMBIENT AIR QUALITY CRITERION (AAQC) OF 50 $\mu g/m^3$

INHALABLE PARTICULATES (PM_{10}): The term PM_{10} has been given to the fraction of total suspended particulates with a diameter of 10 microns or less. This is the particle size most likely to be inhaled and deposited into the thoracic region of the lung.

SOURCES: Inhalable particulate matter is emitted from industrial processes. These include fuel combustion, incineration, construction, mining, smelting and processing. In the urban airshed, motor vehicle exhaust, residential wood combustion and road dust are the major sources of inhalable particulate emissions, Figure 3.22. Natural sources of particulates include wind-blown soil, forest fires, ocean spray and volcanic activity.

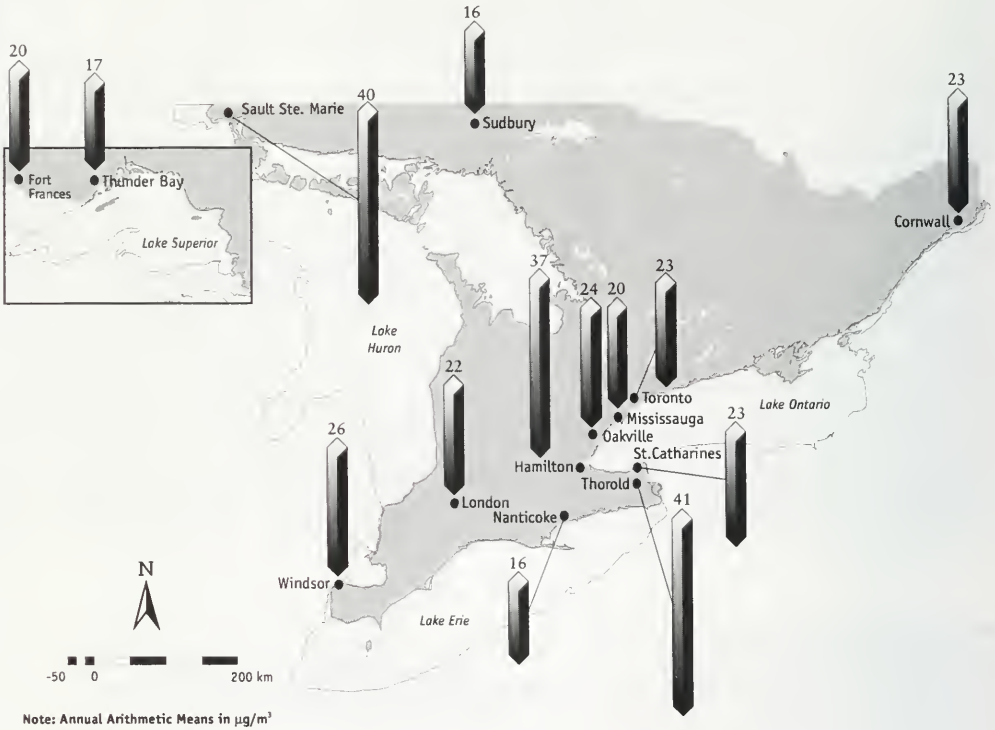
EFFECTS: Major health concerns include breathing and respiratory symptoms, aggravation of existing pulmonary and cardiovascular disease, which can lead to more hospital admissions, damage to lung tissue and premature mortality. PM_{10} also damages materials, and

FIGURE 3.22
ONTARIO PM_{10} EMISSIONS BY SECTORS
(EMISSIONS FROM HUMAN ACTIVITY, 1990 ESTIMATES)



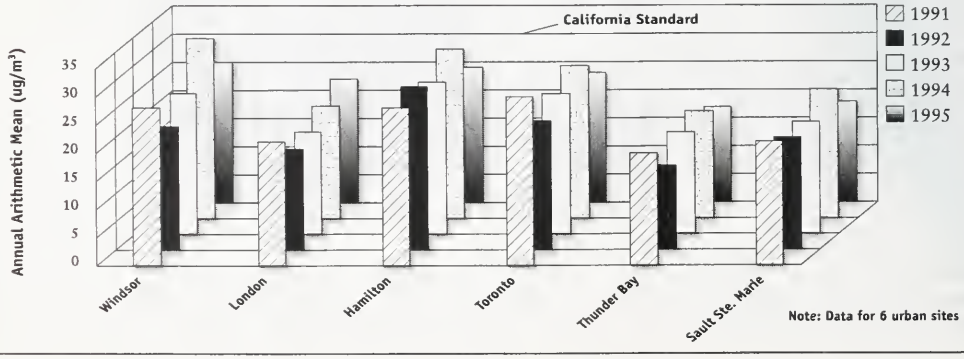
*Emissions from road dusts, construction, agriculture, etc. are not included.

FIGURE 3.23
ANNUAL MEAN PM_{10} CONCENTRATIONS (µg/m³) ACROSS ONTARIO (1995)



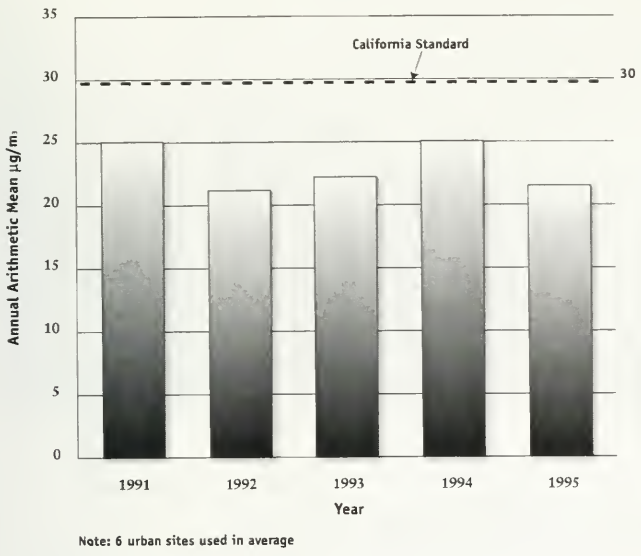
Note: Annual Arithmetic Means in µg/m³

FIGURE 3.24
ANNUAL MEAN PM_{10} LEVELS AT SELECTED SITES ACROSS ONTARIO (1991-1995)



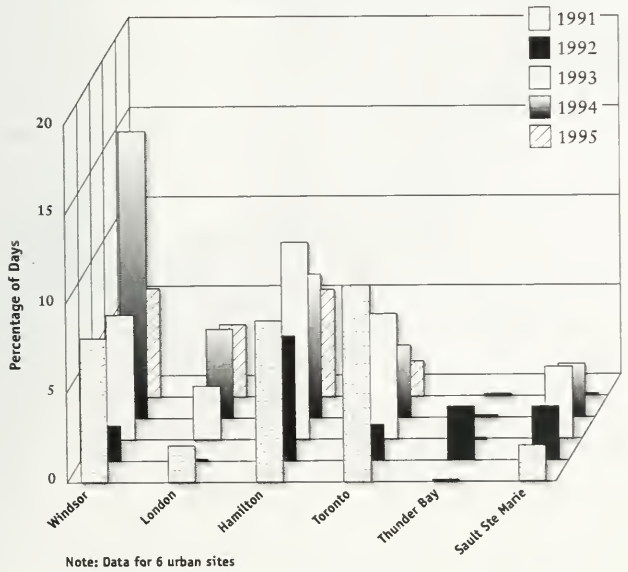
Note: Data for 6 urban sites

FIGURE 3.25
FIVE-YEAR TREND IN PM_{10} (1991-1995)



Note: 6 urban sites used in average

FIGURE 3.26
PERCENTAGE OF DAYS PM_{10} > 50µg/m³ AT SELECTED SITES ACROSS ONTARIO (1991-1995)



Note: Data for 6 urban sites

causes soiling and reduced visibility.

RESULTS FOR 1995: Twenty-four hour PM_{10} levels were measured at 22 locations. Geographical distribution of the 1995 annual mean levels is shown in **Figure 3.23.** As expected, monitoring sites near industrial sources recorded highest annual mean levels, including Thorold, Sault Ste. Marie and Hamilton. These three were the only locations to exceed the California annual standard of 30 µg/m³ for PM_{10} in 1995.

TRENDS: Five-year trends in annual average PM_{10} at selected urban sites across the province are shown in **Figure 3.24.** The California annual standard was not exceeded at any site during the five years. The provincial trend in PM_{10} levels based on data from the same six urban locations is shown in **Figure 3.25.** The provincial composite mean has varied from a low of 21.2 µg/m³ in 1992 to a high of 25.2 µg/m³ in 1994. The 1995 mean of 21.5 µg/m³ is the second lowest mean during the five-year period. The percentage of days on which PM_{10} exceeded 50 µg/m³ at the six urban locations is shown in **Figure 3.26.** In general, Windsor and Hamilton show the highest percentage of days of elevated levels during the five-year period.

At levels above 50 µg/m³ for 24 hours people may experience respiratory problems and aggravation of heart and lung problems.

TRS TOTAL REDUCED SULPHUR

TRENDS IN AMBIENT AIR CONCENTRATIONS

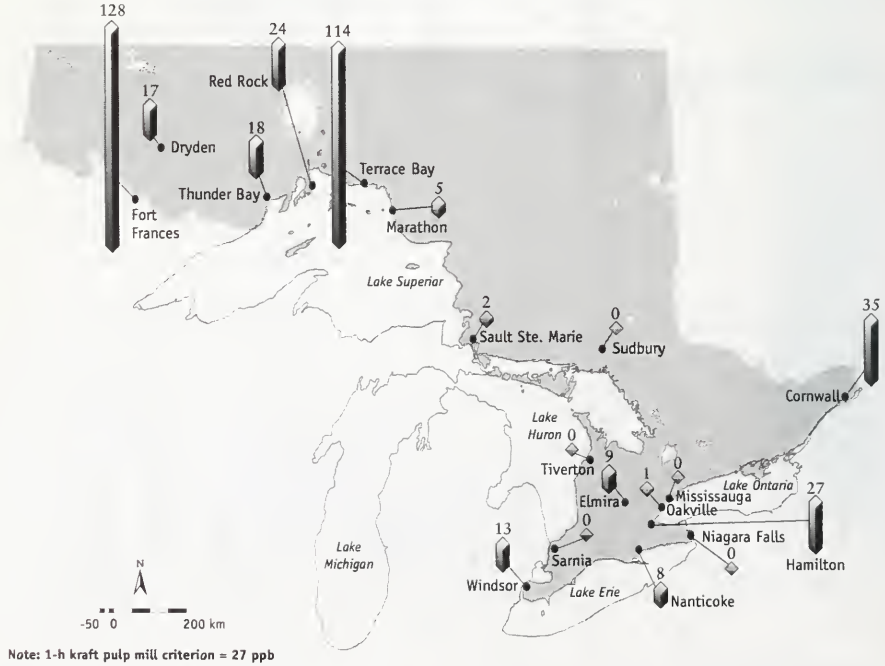
1986-95: .....47 PER CENT DECREASE

1994-95: .....29 PER CENT DECREASE

ONTARIO AMBIENT AIR QUALITY CRITERION (AAQC)

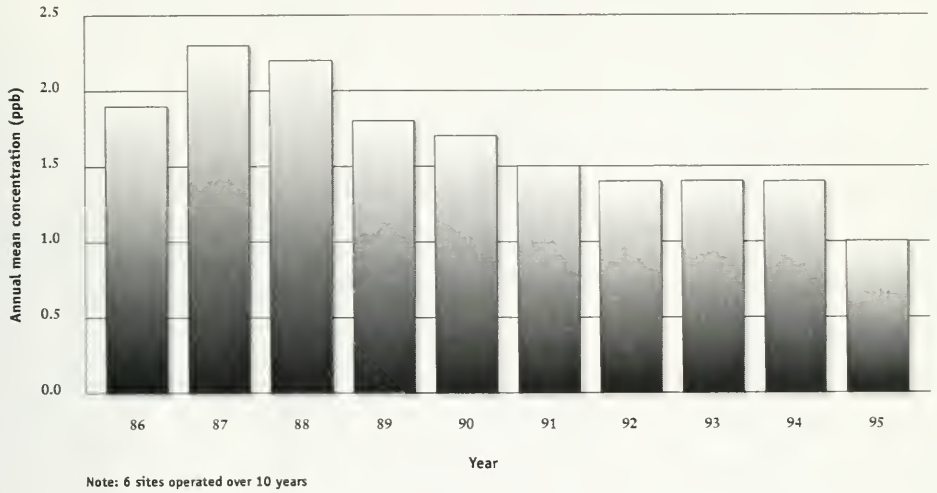
1-HOUR: .....27 PARTS PER BILLION (ppb)
FOR KRAFT PULP MILLS

FIGURE 3.27
GEOGRAPHICAL DISTRIBUTION OF THE NUMBER OF TRS ONE-HOUR CONCENTRATION ABOVE 27 ppb ACROSS ONTARIO (1995)



Note: 1-h kraft pulp mill criterion = 27 ppb

FIGURE 3.28
10-YEAR TREND FOR TRS



Note: 6 sites operated over 10 years

TOTAL REDUCED SULPHUR: TRS produces offensive odors similar to rotten eggs or cabbage.

SOURCES: Industrial sources of TRS include the steel industry, pulp and paper mills, refineries and sewage treatment facilities. Natural sources include swamps, bogs and marshes.

EFFECTS: While TRS compounds are not normally considered a health hazard, they are a primary cause of odors.

RESULTS FOR 1995: Monitoring for TRS was carried out at 34 locations. The highest annual mean (2.5 ppb) and greatest number of instances (128) when the one-hour TRS kraft pulp mill criterion was exceeded were recorded at Fort Frances. The highest one-hour concentration (211 ppb) was measured at Red Rock. Figure 3.27 shows the spatial distribution across Ontario of instances when the one-hour kraft pulp mill criterion was exceeded. As expected, the highest numbers for exceeding the criterion were in communities with kraft pulp mills and/or steel mills.

TRENDS: Provincial TRS levels decreased 47 per cent during the 10-year period and 29 per cent in the final year, Figure 3.28. This is mainly attributable to abatement and regulatory action by the ministry.

CHAPTER 4

AIR QUALITY INDICES AND METEOROLOGY

The Ontario Ministry of Environment and Energy operates an extensive network of air quality monitoring sites across the province. In 1995, 29 of these were in 24 urban centres and constituted the real-time air quality index information system. This system, in place since 1988, provides the public with air quality information across the province. The air quality index (AQI) is based on pollutants which affect health and the environment: sulphur dioxide (SO_2), ozone (O_3), nitrogen dioxide (NO_2), total reduced sulphur (TRS) compounds, carbon monoxide (CO) and suspended particles (SP). The air pollution index (API), based on 24-hour running averages of SO_2 and SP, is included as an AQI sub-index. Not all pollutants are measured at each AQI site.

CALCULATION OF THE AQI

The AQI sub-index is calculated hourly for each pollutant. The highest sub-index at the given hour becomes the AQI. The index increases as air quality deteriorates. The index values, corresponding categories and potential health and environmental effects are given in Table 4.1.

If the AQI value is in the range from 32 to 49 there may be some adverse health effects on sensitive individuals. An index value in the range from 50 to 99 may have adverse effects on the most sensitive of the human or animal population, or may cause significant damage to vegetation and property. An AQI value of 100 or more may cause adverse effects to the health of a large sector of those exposed.

SYSTEM OPERATION

The computer centre at the Environmental Monitoring and Reporting Branch continually obtains data from 29 sites. Indices are recorded hourly every day of the year.

Computed air quality indices and AQI forecasts are then released to the public and news media at regular intervals.

If an AQI station records an index of 32 or above, public information is updated regularly until it drops below 32. Above 50, the local medical officer of health is informed.

"Based on the total number of monitored hours (254,000), on average, good to very good air quality readings were reported 94.7 per cent of the time."

CHANGES TO THE OZONE SUB-INDEX AND IMPLICATIONS

Threshold concentrations for ozone sub-index categories were changed in 1995 to reflect new scientific findings. Previously, the threshold for moderate air quality due to ozone was reached at 81 ppb and for poor quality at 120 ppb. The new thresholds are 50 and 81 ppb respectively, Table 4.2. The number of times the ozone sub-index exceeded 31 increased four to five-fold.

SUMMARY AIR QUALITY INDEX LEVELS (1995)

The frequency distribution of hourly AQI, according to descriptive category and to pollutant responsible for AQI above 31, is shown for the 29 AQI monitoring locations in Table 4.3. Except at Fort Frances, ozone was the most frequent cause of readings over 31. Total reduced

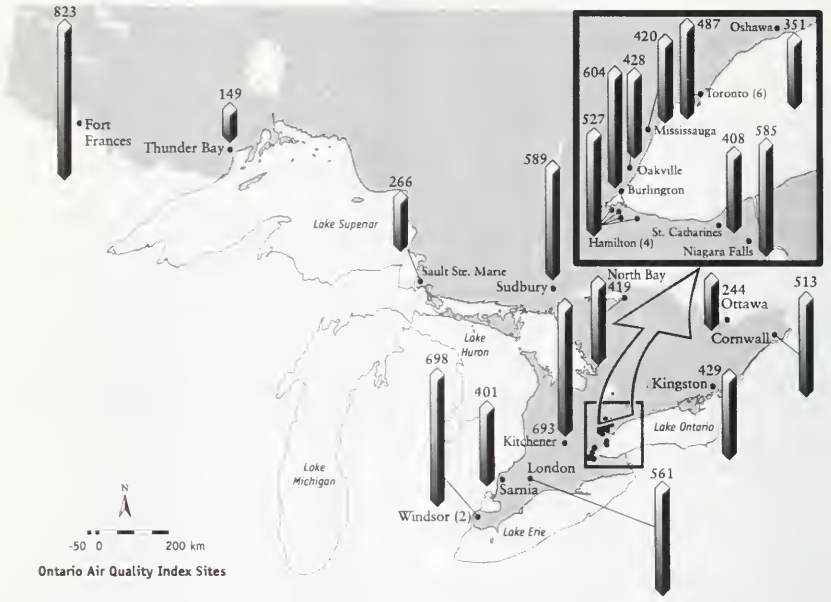
TABLE 4.1 - AIR QUALITY INDEX POLLUTANTS AND THEIR IMPACT

INDEX	CATEGORY	CARBON MONOXIDE (CO)	NITROGEN DIOXIDE (NO_2)	OZONE (O_3)	SULPHUR DIOXIDE (SO_2)	SUSPENDED PARTICLES (SP)	SO_2 + SP (AS MEASURED BY THE API)	TOTAL REDUCED SULPHUR (TRS)
0-15	Very good	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects	No known harmful effects
16-31	Good	No known harmful effects	Slight odor	No known harmful effects	Damages some vegetation in combination with ozone	No known harmful effects	No known harmful effects	Slight odor
32-49	Moderate	Blood chemistry changes, but no noticeable impairment	Odor	Respiratory irritation in sensitive people during vigorous exercise; people with heart/lung disorders at some risk; damages very sensitive plants	Damages some vegetation	Some decrease in visibility	Damages vegetation (i.e. tomatoes, white beans due to sulphur dioxide)	Odor
50-99	Poor	Increased symptoms in smokers with heart disease	Air smells and looks brown. Some increase in bronchial reactivity in asthmatics	Sensitive people may experience irritation when breathing and possible lung damage when physically active; people with heart/lung disorders at greater risk; damage to some plants	Odorous; increasing vegetation damage	Decreased visibility; soiling evident	Increased symptoms for people with chronic lung disease	Strong odor
100-over	Very poor	Increasing symptoms in non-smokers with heart disease; blurred vision; some dumsiness	Increasing sensitivity for asthmatics and people with bronchitis	Serious respiratory effects, even during light physical activity; people with heart/lung disorders at high risk; more vegetation damage	Increasing sensitivity for asthmatics and people with bronchitis	Severe odor; some people may experience nausea and headaches	Significant effects for asthmatics and people with bronchitis	Severe odor; some people may experience nausea and headaches

TABLE 4.2 - COMPARISON OF OLD AND NEW RANGES OF OZONE CONCENTRATION FOR EACH AQI CATEGORY

	OLD CUTOFF CONCENTRATIONS (ppb)		NEW CUTOFF CONCENTRATIONS (ppb)	
CATEGORY	LOW	HIGH	LOW	HIGH
Very Good	0	50	0	23
Good	51	80	24	50
Moderate	81	120	51	80
Poor	121	199	81	149
Very Poor	>200		>149	

FIGURE 4.1
GEOGRAPHICAL DISTRIBUTION OF THE NUMBER OF HOURS AQI >31 ACROSS ONTARIO (1995)



sulphur compounds were the most frequent cause of high indices in Fort Frances. There were 13,260 hours (5.3 per cent of hours monitored) of moderate/poor air quality recorded at the 29 sites in 1995.

Based on the total number of monitored hours (254,000) at the 29 stations, on average, good to very good air quality readings were reported 94.7 per cent of the time. Good to very good readings ranged from approximately 90 per cent at Fort Frances to 98 per cent at Thunder Bay. More occurrences in the moderate/poor categories at Fort Frances were due to emissions of TRS compounds from kraft pulp mills near the monitor. Of the 13,260 hours in the moderate and poor ranges, 11,772 hours or 88.8 per cent were due to ozone. There were only four hours of moderate or poor air quality due to SO_2 reported in the province for the entire year, all recorded in Sudbury. No hours of very poor air quality were recorded in 1995.

A detailed breakdown by region and pollutants of AQI values greater than 31 is shown in **Table 4.4**. On average there were 514 elevated hours of ozone in southwestern Ontario compared to an average 367 hours in central region; 491 in west central; 356, eastern; 407, northeastern; 157, northwestern. The higher totals in southwestern and west central regions were likely due to U.S. sources. Geographical distribution of AQI hours above 31 is shown in **Figure 4.1**. The breakdown of AQI values issued for each community into very good or good and moderate or poor categories is shown in **Figure 4.2**. The projecting portion of the pie represents moderate or poor air quality.

COMPARISON OF AQI VALUES (1991-1995)

AQI values have been recalculated for 1991-1994 using the new cutoff points for ozone. These are then compared with 1995. **Figure 4.3** and **Table 4.5** compare AQI hours above 31. **Table 4.5** shows the highest number of hours above 31 was in 1991. The second highest number was in 1994. Each year ozone was the pollutant that most often caused the index to exceed 31. Ozone is the pollutant of principal concern in most of the province. The number of hours of poor air quality due to ozone in 1991 and 1995 (years when summer conditions were conducive to high ground-level ozone) were respectively 5.5 and 3.1 times the corresponding hours of 1993.

In northwestern Ontario moderate/poor air quality hours due to

TABLE 4.3 - AIR QUALITY INDEX SUMMARY (1995)

		Number Of Hours AQI In Range					# Of Hours Pollutant Responsible For AQI > 31						
Stn ID	City Name	V-GOOD 0-15	GOOD 16-31	MOD 32-49	POOR 50-99	V-POOR 100+	SP	O_3	TRS	SO_2	API	CO	NO_2
44008	Burlington	5228	2873	543	61	0	26	578	X	0	0	0	0
56051	Cornwall	4379	3868	470	43	0	10	400	103	0	0	0	0
35033	Etobicoke South	5972	2292	438	49	0	66	416	X	0	5	0	0
35003	Etobicoke West	5957	2524	238	17	0	34	221	X	0	0	0	0
62030	Fort Frances	2681	5250	695	128	0	2	185	636	X	X	X	X
29000	Hamilton Downtown	5518	2705	497	29	0	63	404	17	0	42	0	0
29105	Hamilton East	5303	2905	489	38	0	22	503	2	0	0	X	X
29114	Hamilton Mountain	5427	2785	441	33	0	6	450	18	0	0	X	0
29118	Hamilton West	5411	2851	440	35	0	50	402	10	0	13	X	0
52020	Kingston	5078	3015	384	45	0	3	426	X	X	X	X	X
26060	Kitchener	4161	3905	637	56	0	3	690	X	0	0	0	0
15025	London	4969	2643	513	48	0	2	559	X	0	0	0	0
46110	Mississauga	4015	1463	374	46	0	14	406	X	0	0	0	0
27072	Niagara Falls	4808	3356	541	44	0	2	583	X	0	0	X	X
75010	North Bay	3269	4889	378	41	0	0	419	X	X	X	X	X
34020	North York Central	5100	3321	311	28	0	38	301	X	0	0	0	0
44015	Oakville	5233	3099	380	48	0	27	397	4	0	0	0	0
45025	Oshawa	4704	3672	316	35	0	7	344	X	0	0	0	0
51001	Ottawa	5387	3111	220	24	0	1	243	X	0	0	0	0
14064	Sarnia	5013	3297	367	34	0	6	390	5	0	0	0	0
71068	Sault-Ste-Marie	3983	4235	258	8	0	14	218	34	0	0	X	0
33003	Scarborough	5631	2546	409	52	0	22	439	X	0	0	0	0
27067	St Catharines	5376	2966	397	11	0	4	404	X	0	0	0	0
77203	Sudbury	2909	5177	555	34	0	0	585	0	4	0	0	0
63200	Thunder Bay	4844	3767	149	0	0	5	130	14	0	0	0	0
31103	Toronto Downtown	5880	2411	211	10	0	17	204	X	0	0	0	0
12016	Windsor College	5719	2343	625	73	0	10	640	48	0	0	X	X
12008	Windsor University	6020	2256	427	57	0	18	466	X	0	0	0	0
36030	York	5644	2671	389	41	0	61	369	X	X	0	0	0

X Pollutant Not Monitored At This Site.

TABLE 4.4 - NUMBER OF HOURS AQI >31 BY REGION AND POLLUTANT (1995)

			DUE TO									
	AQI hrs >31		O_3		SP		TRS		SO_2		API	
REGIONS	Total hrs.	Hrs. of poor	hrs.	%	hrs.	%	hrs.	%	hrs.	%	hrs.	%
Southwestern [4]	2144	131	2055	(95.8)	36	(1.7)	53	(2.5)	0	0	0	0
Westcentral [7]	3688	211	3436	(93.2)	150	(4.0)	47	(1.3)	0	0	55	(1.5)
Central [10]	3996	184	3675	(92.0)	312	(7.8)	4	(0.1)	0	0	5	(0.1)
Eastern [3]	1186	53	1069	(90.1)	14	(1.2)	103	(8.7)	0	0	0	0
Northeastern [3]	1274	61	1222	(96.0)	14	(1.0)	34	(2.7)	4	(0.3)	0	0
Northwestern [2]	972	53	315	(32.4)	7	(0.7)	650	(66.9)	0	0	0	0

[ ] - indicates number of sites
( ) - indicates percentage of time pollutant contributed to the hours that AQI was greater than 31 in each region

TABLE 4.5 - NUMBER OF HOURS AQI >31 BY REGION AND POLLUTANT (1991-1995)

	1991		1992		1993		1994		1995	
Regions	Moderate	Poor	Moderate	Poor	Moderate	Poor	Moderate	Poor	Moderate	Poor
Southwestern [4]	2384	396	1696	124	1687	110	1890	157	1932	212
Westcentral [7]	4846	631	2855	114	3425	81	4123	204	3442	246
Centrol [10]	4430	613	2796	123	2951	118	4210	236	3609	387
Eastern [3]	1382	152	795	69	927	19	1229	25	1074	112
Northeostern [3]	1051	60	959	45	679	17	740	18	1191	83
Northwestern [2]	996	251	983	313	832	329	684	75	844	128
Total Hours > 31	15089	2103	10087	785	10501	674	13053	715	12092	1168
Hours due to Ozone	13293	1792	8238	433	8781	328	11227	623	10760	1012
Hours due to SP	535	5	701	9	793	7	988	3	528	5
Hours due to TRS	1246	301	1089	341	882	331	722	87	742	149
Hours due to SO_2	3	5	9	2	6	8	3	2	2	2
Hours due to API	12	0	50	0	39	0	113	0	60	0

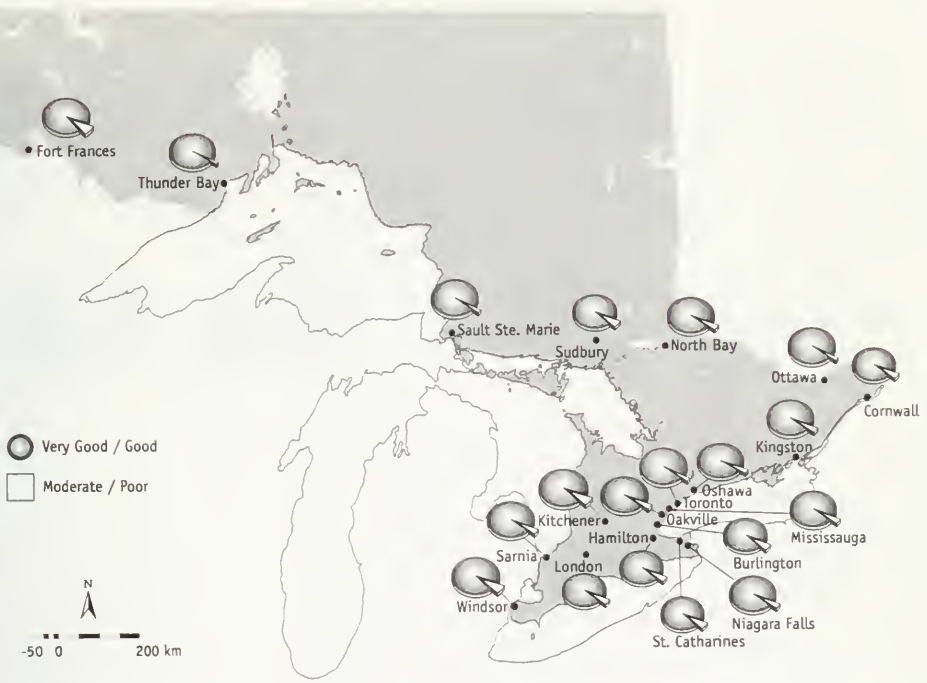
[ ] indicates number of sites

TRS (the pollutant of concern in this area) occur at Fort Frances, near kraft pulp mills.

The 1991-1995 trend (**Figure 4.3**) for TRS shows a remarkable decline in the number of hours of moderate to poor air quality.

Poor air quality due to SO_2 was recorded for two hours at the Sudbury Science North site. Moderate to poor air quality due to NO_2 and CO was not reported at all during the five years. **Figure 4.4** shows pie diagrams for very good to good and moderate to poor air quality across Ontario

FIGURE 4.2
SUMMARY OF VERY GOOD/GOOD AND MODERATE/POOR CATEGORIES AT AQI SITES ACROSS ONTARIO (1995)



1991-1995. Each pie on the left shows total percentages and the corresponding pie at right breaks down the slice that indicates moderate to poor air quality into the percentages of pollutants which pushed the AQI above 31. The pie diagrams show AQI in very good to good categories more than 93 per cent of the time over the five years. Ozone registered in the moderate to poor categories more than 80 per cent of the time when the index was above 31.

AIR QUALITY ADVISORY

The Ontario Ministry of Environment and Energy and Environment Canada joined forces in 1993 to issue public air quality advisories when elevated air pollution due to ground-level ozone was forecast.

FIGURE 4.3
FIVE-YEAR TREND FOR AQI >31 BY POLLUTANT (1991-1995)

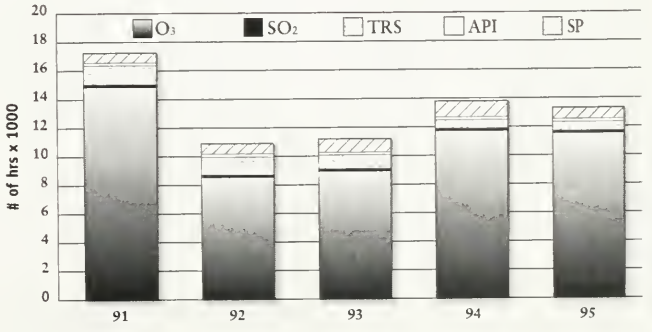
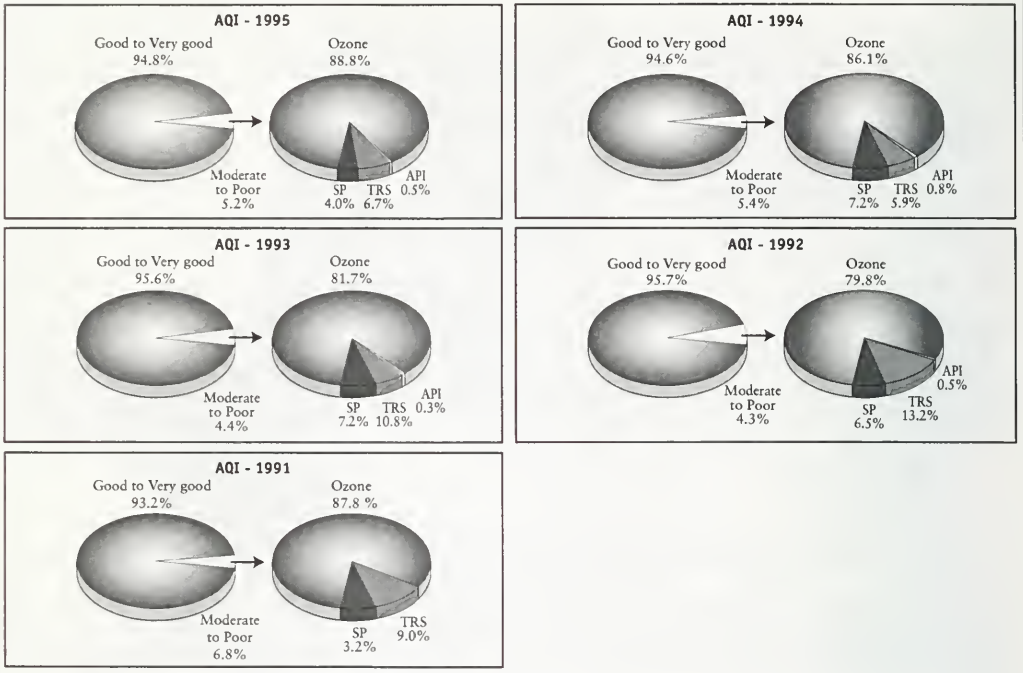


FIGURE 4.4
SUMMARY OF AQI BY CATEGORY AND POLLUTANT (1991-1995)



This program builds on Ontario's air quality index (AQI).

These advisories are based on provincial AQI forecasts for ground-level ozone. They are issued regionally in the late afternoon the day before expected elevated levels. Advisories are made public via the news media, weather offices and weather radio. They are also available at local ministry offices.

Air quality advisories were issued six times in 1995. One of these lasted four days (June 16-19) while two lasted two days (July 14-15 and August 14-15). The other three were for June 24, July 25 and July 31.

SYNOPSIS OF AIR QUALITY ADVISORY JUNE 16-19, 1995

The first advisory of 1995 was issued Thursday, June 15 for Friday, June 16, the first day of a four-day episode. Sunny and hot conditions with light to moderate winds were forecast over the next few days due to a slow-moving high pressure system. On the first day, the advisory was issued for southwestern and northeastern Ontario. The highest ozone concentrations on June 16 were recorded at North Bay and Sudbury AQI sites (93 and 92 ppb respectively). On the afternoon of June 16, the advisory was extended to Saturday, June 17 and the west central and central region areas were also included. On June 17, the highest ozone concentration was recorded at the Sudbury AQI site (119 ppb), and in the central area, the Etobicoke South monitor recorded the highest concentration (106 ppb). On the afternoon of Saturday, June 17, the advisory was extended to southeastern Ontario for Sunday, June 18 as the stagnant weather pattern continued to dominate the weather across southern and northeastern Ontario. On June 18, Windsor recorded 115 ppb, Hamilton West 93 ppb, Oshawa 107 ppb, Kingston 114 ppb and Sudbury 98 ppb. On June 19, the last day of the episode, Windsor recorded 101 ppb, Niagara Falls 100 ppb, and Kingston 109 ppb. A copy of the air quality advisory issued on June 17, 1995 is shown on the next page.

AIR POLLUTION INDEX (API)

The API, the basis of an alert and control system to warn of deteriorating air quality, is derived from 24-hour running averages of SO_2 and SP. Research studies have linked respiratory illness to elevated concentrations of SO_2 and particulates.

Regulation 346 under the *Environmental Protection Act* (1971) authorizes the Minister of Environment and Energy to order any source not

essential to public health or safety to curtail or cease operations when air pollution levels may be injurious to health.

OPERATION OF THE SYSTEM

The API is computed each hour, based on the past 24 hourly values for SO_2 and SP. If the index reaches 32 and if the meteorologist predicts a continuation of adverse atmospheric conditions for at least six hours, an air pollution advisory is issued. Managers of significant sources of pollution are advised to prepare for possible curtailment of operations.

If the index reaches 50, and if at least six hours of adverse atmospheric conditions are forecast, owners of major sources may be ordered to curtail operations. This is the first-level alert.

A second alert is issued at 75. Further curtailment may be ordered.

The threshold level of an air pollution episode occurs at an API of 100. If atmospheric conditions are not expected to improve for at least six hours, owners of all sources not essential to public health or safety may be ordered shut down.

AIR POLLUTION INDEX LEVELS

A history of air pollution index levels during the last five years is

EXAMPLE:
AIR QUALITY ADVISORY ISSUED JUNE 17, 1995.

Air quality advisory number w003 issued jointly by the Ontario Ministry of Environment and Energy and Environment Canada.
Toronto, Ontario.
Issued at 3 p.m. Saturday, 17 June 1995.
Air quality advisory issued for:

SOUTHERN ONTARIO AND NORTHEASTERN ONTARIO

Sunday is SPARE THE AIR DAY...a day of elevated air pollution when everyone is encouraged to spare the air by taking public transit or by car pooling. The air quality index is expected to exceed the moderate threshold of 32 and possibly reach the poor level...due to ground-level ozone.

Sunny and hot conditions with light to moderate winds will dominate the weather Sunday due to a stagnant weather pattern. Pollutants from U.S. and Ontario sources will react in sunlight to form photochemical smog.

You can help reduce air pollution by car pooling...using transportation alternatives... refraining from using gas-powered motors, aerosol sprays and solvents.

During the episode, individuals may experience eye irritation. Heavy outdoor exercise may cause respiratory symptoms such as coughing or shortness of breath. People with heart or lung disease, including asthma, may experience a worsening of their condition.

Elevated levels of photochemical smog result in crop losses of up to $70 million annually in Ontario.

Higher pollution levels are expected to persist into Monday.

TABLE 4.6 NUMBER OF OCCASIONS API >31 AT AQI SITES ACROSS ONTARIO (1991-1995)

STATION	1991	1992	1993	1994	1995
BURLINGTON				1 (36)	
ETOBICOKE WEST				2 (33)	
ETOBICOKE SOUTH				1 (37)	1 (32)
HAMILTON DOWNTOWN	1 (34)	3(35)	3 (37)	3 (37)	3 (39)
HAMILTON EAST			1 (33)		
HAMILTON			1 (33)		1 (37)
HAMILTON WEST				1 (34)	
SCARBOROUGH				1 (42)	
WINDSOR UNIVERSITY				1 (32)	

Note: Maximum API value is given in the parenthesis

provided in Table 4.6. Hamilton Downtown is the only site that reached API advisory levels each year, 1991-1995. In 1995 there were five such incidents at three sites; two Hamilton sites and the Etobicoke South site. The Toronto Downtown site did not reach the advisory level in the years 1991 through 1995.

LAMBTON INDUSTRY METEOROLOGICAL ALERT (LIMA)

The Lambton industry meteorological alert system is covered by the *Environmental Protection Act* - Regulation 350. Application is limited to that part of the county of Lambton bounded by Lake Huron, the St. Clair River, Highway 80, Moore Township Road 31 and its continuation through that part of Highway 40, and Lambton County Road 27, which includes the City of Sarnia.

The Minister may declare an alert when the 24-hour running average sulphur dioxide concentration at any station in the LIMA system reaches 0.07 ppm and meteorological forecasts predict six hours or more of conditions conducive to elevated SO_2 concentrations. The alert is issued at 0.07 ppm to prevent exceeding the Ontario 24-hour SO_2 AAQC (0.10ppm).

Two monitoring sites are located in Sarnia (Front Street and Centennial Park), one in Corunna (River Bend) and one in Michigan (Port Huron).

The alert was issued six times in 1995, the longest being for 26 hours from 10 a.m. May 1 to noon May 2. The maximum 24-hour running average SO_2 concentration during this episode reached 0.089 ppm, recorded at the River Bend site. This concentration was also the highest 24-hour running average SO_2 recorded at the monitors in the LIMA system in 1995. There were no instances of exceeding the 24-hour SO_2 AAQC in the LIMA system.

Of the six alerts issued for the Sarnia area, three were based on SO_2 measurements at Front Street and the remaining three at River Bend. LIMA alerts called during the last 10 years are in Table 4.7.

METEOROLOGY AND AIR QUALITY

General meteorological influences

Weather is a major influence on provincial air quality. Air pollution is affected by wind, temperature, stability, precipitation and sunshine. Topographical features, such as valleys, and the nature of the terrain, such as buildings and trees, affect local air quality significantly.

METEOROLOGY AND ITS INFLUENCE ON AIR POLLUTANTS

Suspended particulates: In Ontario, light winds are associated with slow-moving high-pressure cells. This weather pattern, with low-level temperature inversions and limited vertical mixing, contributes to pollution buildup, especially of suspended particulates (SP). This type of weather occurs in both warmer and cooler months, leading to undesirable air quality. Suspended particulates are of concern throughout the year.

Ozone: Ground-level ozone is a component of photochemical smog, formed when volatile organic compounds (VOCs) and oxides of nitrogen (NO_x) react in sunlight. Ozone is not directly emitted in large amounts into the atmosphere but is formed downwind from precursor sources. It can travel long distances in the atmosphere. Widespread elevated ozone episodes occur in late spring and summer under a high pressure system. On such days, air generally reaches southern Ontario from the southwest, having crossed heavily industrial and urban areas of the eastern and mid-western U.S. These are potential sources of ozone and its precursors. Air quality advisories due to ground-level ozone are likely to be issued during this type of weather.

Total reduced sulphur: Total reduced sulphur compounds are emitted by a number of Ontario industries, especially pulp and paper

TABLE 4.7 - LAMBTON INDUSTRY METEOROLOGICAL ALERT SUMMARY 1986-1995

Year	Alerts called	Average duration (hrs)
1986	8	14
1987	0	-
1988	5	24
1989	3	12
1990	9	16
1991	8	23
1992	3	13
1993	7	15
1994	7	19
1995	6	18

mills, iron and steel operations and refineries. Wind is the major factor in determining which areas will be affected. Effect is greatest at night or early morning under a temperature inversion. These factors are the major cause contributing to the high number of instances of elevated levels of TRS at Fort Frances and, to a lesser extent, at Cornwall.

METEOROLOGICAL CONTROLS IN SELECTED AREAS

Suspended particulates in Hamilton

Suspended particulates are of concern in Hamilton. The industrial complex by the Hamilton harbor is a major source of heat and pollution that affects the local environment. Furthermore, because Hamilton is on Lake Ontario, lake-induced temperature inversions are common in the spring and fall and can result in pollution buildup over the city. Topographical influences include the Dundas valley and the Niagara escarpment, which interact with the lake breeze. The resulting inversion and the urban heat island frequently cause high pollution. These conditions led to the air pollution index reaching the advisory level twice in 1995.

Sulphur dioxide in Sarnia

Sulphur dioxide is a concern in the Sarnia area. Chemical and oil refineries plus a large thermal generating station are the main sources. The area is flat, bounded by Lake Huron on the north and the St. Clair River on the west. The river channels emissions from industries along its banks; the situation is aggravated by the alignment of the river and industries with prevailing southwest winds. The LIMA system was developed to counteract the potential for SO_2 episodes.

Sulphur dioxide in Sudbury

Sulphur dioxide is the most significant airborne contaminant in Sudbury as a result of emissions from INCO and Falconbridge nickel smelters. INCO's tall stack, built in 1972, releases pollutants at great heights over a wide area. This, in combination with significantly reduced emissions, has resulted in lower average sulphur dioxide levels locally. However, the problem of short-term fumigation, which occurs under sunny conditions, light winds and temperature inversions, has not been completely eliminated.

SUMMARY OF METEOROLOGICAL CONDITIONS - 1995

In general, Ontario recorded higher than normal annual mean temperatures in 1995. Precipitation was also up, with more rainfall but less snowfall. Total bright sunshine hours showed no definite trend.

Associated with this relative warmth, ground-level ozone readings were higher in 1995 than in the previous three years. For example, in July, normally the hottest period of the year, the mean maximum temperature was typically half a degree Celsius higher than the normal mean. Table 4.8 shows the number of days in 1995 with temperatures above 30 degrees C for several Ontario cities. Windsor recorded 24 days above 30 degrees C; Ottawa 19; Kitchener and London, each 13. In fact, every weather reporting site recorded more days with temperatures higher or equal to 30 degrees C in 1995 than in 1994. In the last eight years, only 1988 and 1991 recorded more of these days than 1995. Correspondingly, the highest number of days when ozone concentrations of more than 80 ppb were widespread across Ontario occurred in 1988. Second highest was 1991 and third highest, 1995. This indicates a correlation between the number of days with widespread ozone concentrations and the number of above average hot days.

TABLE 4.8 - NUMBER OF DAYS MAXIMUM AIR TEMPERATURE >30 DEGREES CELSIUS

STATION	1988	1989	1990	1991	1992	1993	1994	1995
WINDSOR	52	18	13	41	2	19	17	24
SUDBURY	21	10	0	14	0	4	4	9
OTTAWA	23	17	15	22	6	9	9	19
KINGSTON	12	2	2	6	0	1	3	8
TORONTO	38	12	9	21	2	11	10	12
THUNDER BAY	15	8	3	11	2	2	–	8
KITCHENER	29	10	2	11	1	6	8	13
LONDON	30	7	1	16	0	6	7	13

CHAPTER 5

MOBILE AMBIENT AIR MONITORING

In the early 1980s it was realized that stationary monitoring was incapable of responding adequately to all air pollution problems. Consequently the ministry developed mobile units for rapid, onsite monitoring of ambient air pollutants.

THE MOBILE TAGA: Figure 5.1 shows a mobile unit equipped with a tandem mass spectrometer (MS/MS) known as the trace atmospheric gas analyzer (TAGA). TAGA can detect inorganic and volatile organic compounds (VOCs) to less than one part per billion (ppb). Unique features of the mobile TAGA include real-time detection, identifying pollution sources, characterization of odors and rapid response to environmental emergencies such as chemical spills or fires. Onboard instruments continuously record wind speed and direction which help in locating and identifying pollution sources. The ministry operates two mobile TAGAs: Pioneer, dedicated to real-time detection of air pollutants, and Explorer, dedicated to onsite cartridge air sample analysis of VOCs using gas chromatography - MS/MS.

AIR POLLUTION SOURCES: TAGA has monitored emissions from industries producing fibreglass, wire, PVC plastics, leather, paper, cement, shingles, lubricants, resins, paints, plus emissions from petrochemical refineries, storage tanks, wood treatment facilities, distilleries, foundries, landfills, vehicle exhaust, and waste treatment sites.

AIR POLLUTANTS: TAGA has monitored for hundreds of air pollutants of various chemical classes such as alcohols, aldehydes, ketones, amines, sulphides, mercaptans, aromatics, phenols, acids, PAHs and PCBs. Pollutants not detectable by TAGA methods are monitored by separate analysers (e.g. mercury, ozone, carbon monoxide) installed in the mobile unit.

USE OF DATA: In the past eight years the TAGA has been used extensively for specialized air monitoring surveys across Ontario. The data have been used for health-risk assessment, abatement programs and in judicial proceedings.

> *"In the past eight years the TAGA (trace atmospheric gas analyzer) has been used extensively for specialized air monitoring surveys across Ontario."*

FIGURE 5.1
THE MOBILE TAGA AIR MONITORING UNIT

Case study: Odorous Air Pollutants

Styrene: Used in making plastics, synthetic rubber, fibreglass.

Ministry standard: 400 µg/m³

Odor threshold: 20 µg/m³

The objective was to characterize odors coming from a company producing polyester resins used in glass-reinforced plastics. In 1989 TAGA monitored emissions and identified styrene as the major offender. Styrene levels as high as 155 µg/m³ were recorded. The minimum odor threshold for styrene is only 20 µg/m³.

In 1993 a thermal destruction unit was installed by the company. The number of odor complaints reported to the ministry by nearby residents in 1993-94 was noticeably lower. In 1995 TAGA monitored the company's emissions to test the thermal destructor. The maximum level of styrene was 27 µg/m³, slightly above the odor threshold, and several micrograms lower than previous measurements. Figure 5.2 shows the effect of the thermal destructor in reducing the styrene odor impact in the area.

FIGURE 5.2
STYRENE - FIBREGLASS MANUFACTURING WITH AND WITHOUT THERMAL DESTRUCTOR

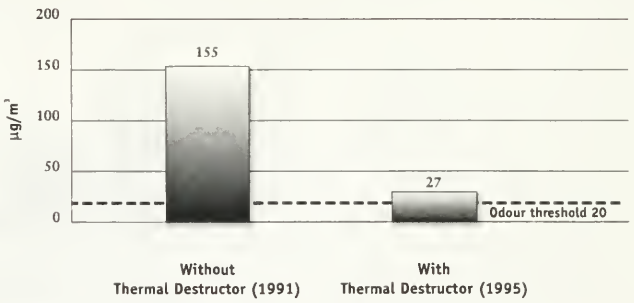
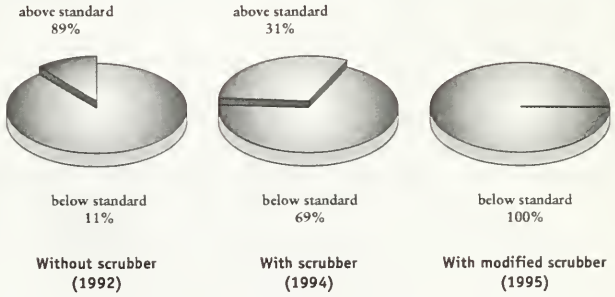


FIGURE 5.3
HYDROGEN FLUORIDE - ALUMINUM CASTINGS PLANT WITHOUT SCRUBBER AND WITH MODIFIED SCRUBBER



Case Study: Corrosive Air Pollutants

Hydrogen fluoride (HF) and hydrogen chloride (HCl): colorless gases, irritating and pungent odors.

Ministry standard: 4.3 µg/m³ (HF)
100 µg/m³ (HCl)

The objective was to measure levels of hydrogen fluoride (HF) and hydrogen chloride (HCl) near an aluminum castings plant. This plant manufactures parts for the automotive industry. In 1992 TAGA detected HF and HCl levels higher than allowable ministry limits. A scrubber for HF and HCl was installed in 1993. In 1994 TAGA found HF and HCl levels to be lower; however HF levels were higher than the allowable limit. Modifications to the scrubber were carried out following the air study. HF and HCl were again measured by TAGA in 1995. It is obvious from **Figure 5.3** that the modified scrubber reduced HF levels substantially in the local air.

Case study: toxic air pollutants

Mercury (Hg): Used in thermometers, mirrors, fluorescent lamps and chlorine production.

Ministry standard: 5000 nanograms per cubic metre (ng/m³)

A major industry in Cornwall was monitored in 1993 for elemental Hg vapor by a highly sensitive mercury analyser installed in the mobile TAGA air monitoring unit. The Hg analyser provided near real-time ambient Hg levels every five minutes. Hg concentrations measured when the plant was operating were higher than typical urban background levels (approximately 2 ng/m³) but several times lower than the ministry standard. The plant was closed in March 1995 and all mercury stored in a small building referred to as the cell room.

In July 1995, Hg levels in the vicinity of the cell room were found to be similar to those when the plant was

open. Also, levels measured near the cell room and farther away in the residential area showed a similar pattern to 1993. An example of the maximum Hg levels recorded at different distances from the cell room is shown in **Figure 5.4.** Hg levels were highest near the cell room, rapidly decreasing to background levels approximately two kilometres away. It was concluded that the cell room was the main source of Hg. All mercury from the cell room was then removed and cleanup was done.

A few months later, another TAGA survey was conducted and, surprisingly, Hg was still detected. The main source of Hg was the empty cell room and to a lesser extent contaminated soil onsite. Overall average concentration of Hg for each survey is shown in **Figure 5.5.** Since the plant closure Hg levels have been decreasing steadily and this downward trend is expected to continue. Further decontamination of the cell room and onsite soil is being carried out in an effort to minimize Hg emissions. The final phase of Hg measurements by TAGA will be conducted once decontamination is complete.

FIGURE 5.4
MAXIMUM MERCURY CONCENTRATION VERSUS DISTANCE FROM SOURCE

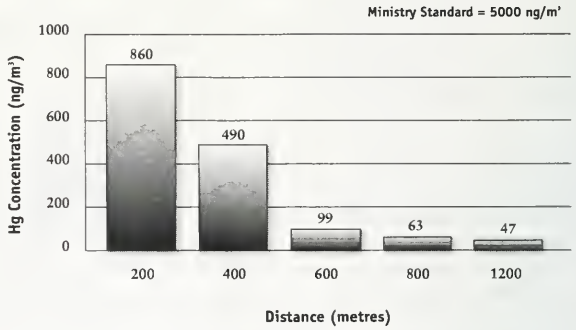
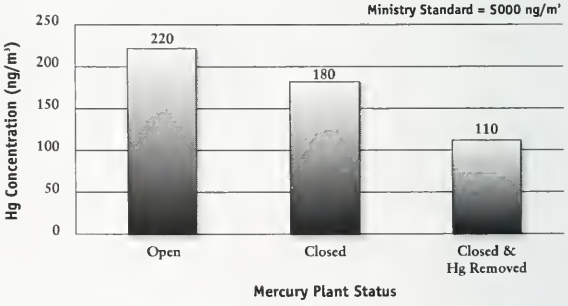


FIGURE 5.5
SURVEY AVERAGE MERCURY CONCENTRATIONS



ORGANIC COMPOUNDS

VOLATILE AND SEMI-VOLATILE ORGANIC COMPOUNDS: Includes both volatile organic compounds (VOCs) such as trichloroethylene and benzene, and semi-volatile organic compounds (SVOCs) such as polycyclic aromatic hydrocarbons (PAHs) and dioxins and furans.

SOURCES: Most VOCs and SVOCs are emitted to the atmosphere directly from industrial/commercial processes – for example, steel making, general solvent use and motor vehicles – or as products of incomplete combustion such as emissions from wood stoves and residential oil furnaces. Some organic compounds such as formaldehyde are also formed in the atmosphere as a result of photochemical processes.

EFFECTS: These chemicals are of concern because they are persistent and bio-accumulative, or because they contribute to ground-level ozone. Some are known or suspected human carcinogens or contribute to ground-level ozone.

"Twenty-eight VOCs (volatile organic compounds) were monitored at 18 Ontario sites. Measured concentrations were well below existing guidelines."

FIGURE 6.1
VOC MONITORING SITES IN ONTARIO (1995)

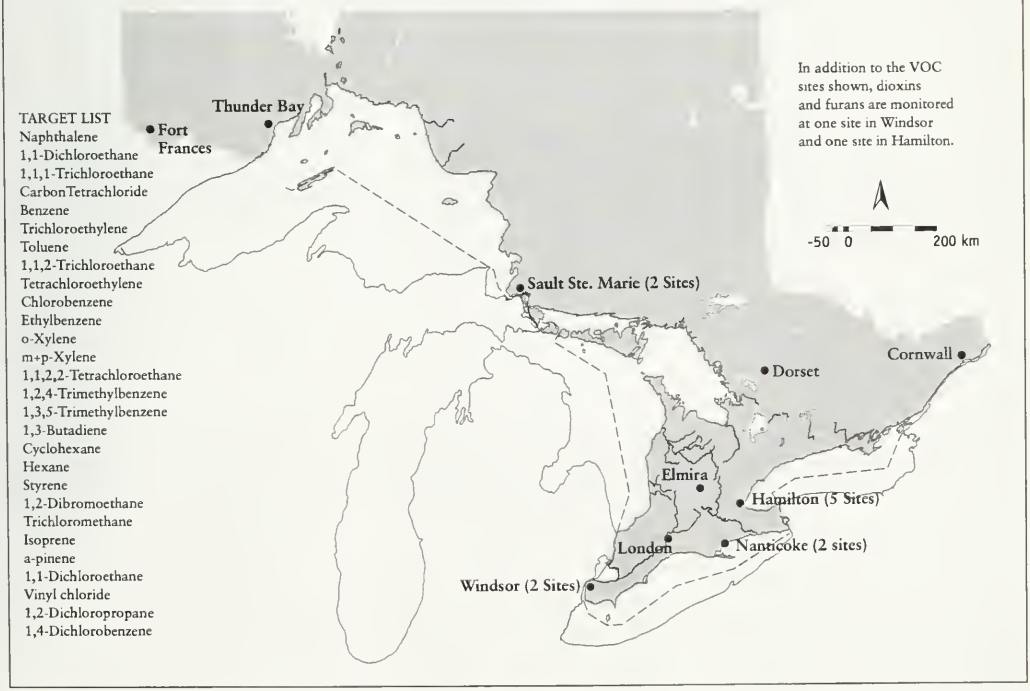
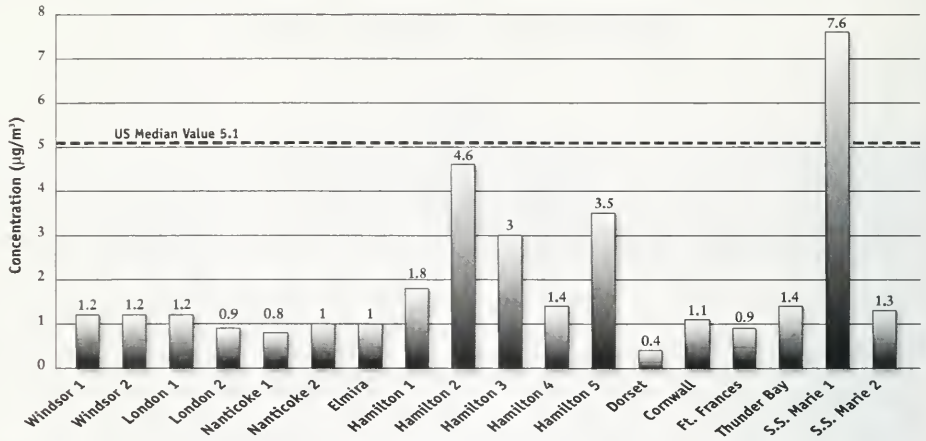


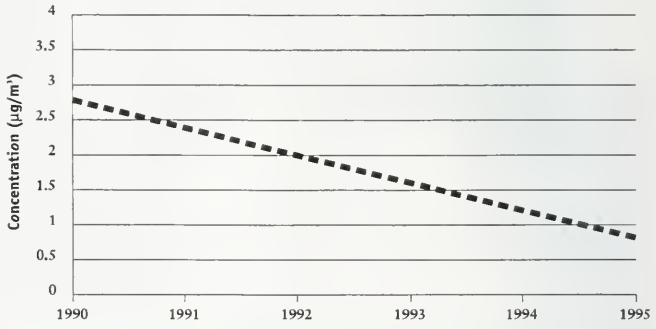
FIGURE 6.2
MEDIAN BENZENE CONCENTRATIONS - 1995 VS. U.S. URBAN/SUBURBAN MEDIAN



RESULTS FOR 1995: Twenty-eight VOCs were monitored at 18 Ontario sites, **Figure 6.1**. Measured concentrations were well below existing guidelines. Concentrations were typically a few micrograms per cubic metre (µg/m³) at most monitors. Exceptions occurred near known sources. For example, benzene concentrations at an industrial site in Sault Ste. Marie averaged 11.4 µg/m³ with a maximum of 52.2 µg/m³. Benzene concentrations tended to average less than three µg/m³ in most other areas. In the United States, the median benzene concentration from more than 10,000 measurements in urban and suburban areas was 5.1 µg/m³. **Figure 6.2** shows Ontario median benzene concentrations compared to the U.S.

Table 6.1 shows median concentrations of several common VOCs. For comparison, the U.S. median concentration from urban/suburban sites is also shown. Ontario median concentrations were generally lower than U.S. urban median concentrations. The exceptions were ethylbenzene and m+p-xylene at one site in London. However, this site has only half a year of record and these results will need to be reconfirmed. Not surprisingly, known sources produced somewhat higher readings than sites with no specific source nearby.

FIGURE 6.3
MEDIAN BENZENE CONCENTRATIONS FOR WINDSOR



The 24-hour guideline for dioxins and furans is five picograms toxic equivalent/m³ (pg TEQ/m³). Ambient air concentrations in Hamilton, Windsor and Dorset were well below the guideline. Maximum measured values were 0.41 pg TEQ/m³, 0.07 pg TEQ/m³ and 0.008 pg TEQ/m³ respectively. Average values were 0.05, 0.13, and 0.005 pg TEQ/m³ for the same three sites. The most toxic dioxin isomer – 2,3,7,8-T4CDD – was detected in two of five samples from Hamilton (contributing 1.5 per cent and three per cent to the total toxic equivalence); in two of 11 samples from Windsor

TABLE 6.1 - MEDIAN CONCENTRATIONS (µg/m³) FOR SELECTED VOCs (1995)

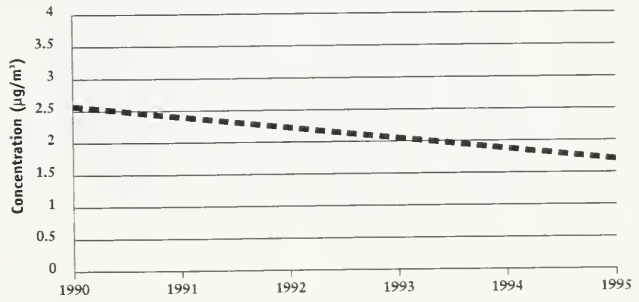
City	Toluene	Ethylbenzene	o-Xylene	m+p-Xylene	Styrene	Chloroform
Windsor 1	2.82	0.38	0.42	1.20	0.10	0.06
Windsor 2	2.95	0.53	0.58	1.93	0.08	0.06
London 1	3.10	0.39	0.44	1.50	0.06	0.06
London 2	2.75	1.35	1.38	4.73	0.03	0.06
Nanticoke 1	1.40	0.18	0.17	0.50		0.04
Nanticoke 2	1.00	0.16	0.16	0.50		0.05
Elmira	7.72	0.36	0.38	1.20	0.03	0.04
Hamilton 1	4.88	0.74	0.74	2.30	0.12	0.05
Hamilton 2	3.45	0.51	0.57	1.70	0.15	0.07
Hamilton 3	6.02	0.87	0.87	3.45	0.16	0.06
Hamilton 4	2.60	0.44	0.48	1.43	0.03	0.05
Hamilton 5	2.80	0.47	0.43	1.50	0.15	0.04
Dorset	0.48	0.08	0.06	0.20		0.04
Cornwall	3.40	0.40	0.50	1.25	0.30	0.16
Fort Frances	1.31	0.24	0.30	0.80	0.06	0.16
Thunder Bay	2.26	0.40	0.52	1.40	0.03	0.06
S.S. Marie 1	3.40	0.32	0.42	1.50	0.23	0.04
S.S. Marie 2	2.42	0.25	0.31	0.89	0.03	0.05
U.S. Median	8.6	1.1	2.2	4.2	0.6	0.2

(blank cells indicate >80% not-detected)

(contributing 4.5 per cent and 5.6 per cent to the total toxic equivalence); and in none of five samples in Dorset.

TRENDS: Interpretation of six years of VOC data has been difficult as not all sites have been operational all six years. Only Windsor and Hamilton have a record from 1990 through 1995. Median benzene concentrations for these two sites are shown in Figure 6.3 and Figure 6.4 respectively. At both sites, median benzene concentrations declined during the six-year period. This decline is statistically significant.

FIGURE 6.4
MEDIAN BENZENE CONCENTRATIONS FOR HAMILTON



CHAPTER 7

INTERNATIONAL AIR QUALITY PERSPECTIVE

How does Metro Toronto's air quality measure up?

STUDY DETAILS: The ministry requested ambient air quality data from 116 cities worldwide. The pollutants considered included criteria contaminants O_3, SO_2, NO_2, CO, TSP and PM_{10}. Forty-six cities responded with 1994 data that could be compared to Toronto. Metropolitan populations range from approximately 100,000 in Halifax to 20 million in Mexico City. Since monitoring techniques may vary, comparisons between cities are subject to caution. And because air quality standards may also vary from country to country, comparisons presented here are referenced to ambient air quality criteria (AAQC) for Ontario and national ambient air quality standards (NAAQS) for the United States.

"Overall, Toronto's air quality during 1994 was better than many other major cities around the world."

OZONE RESULTS: Maximum one-hour

FIGURE 7.1
MAXIMUM ONE-HOUR OZONE CONCENTRATION (ppb) IN SELECTED WORLD CITIES FOR 1994

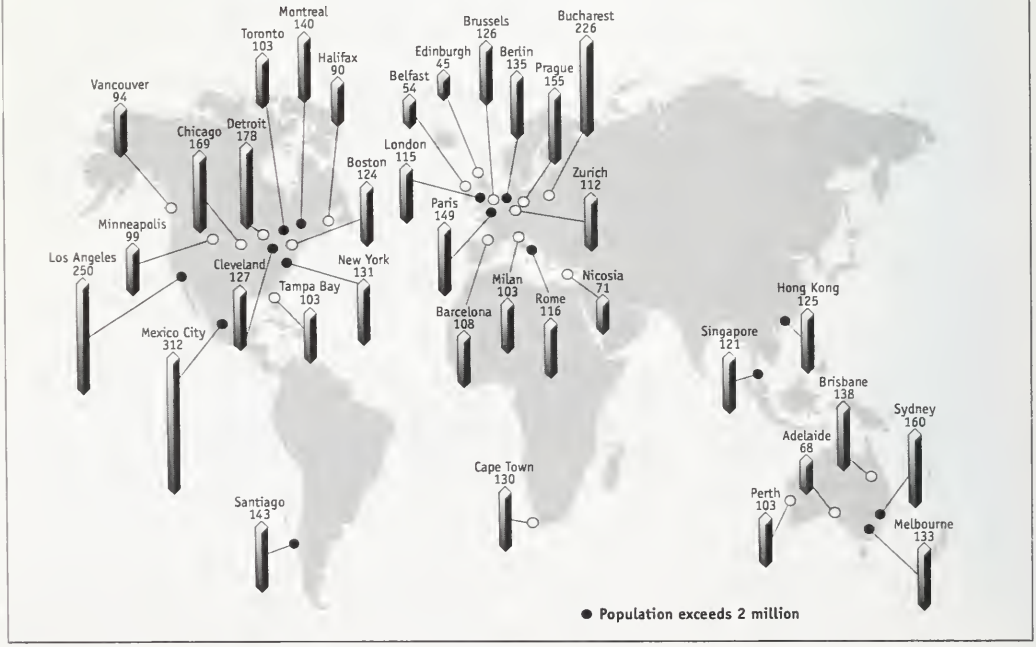
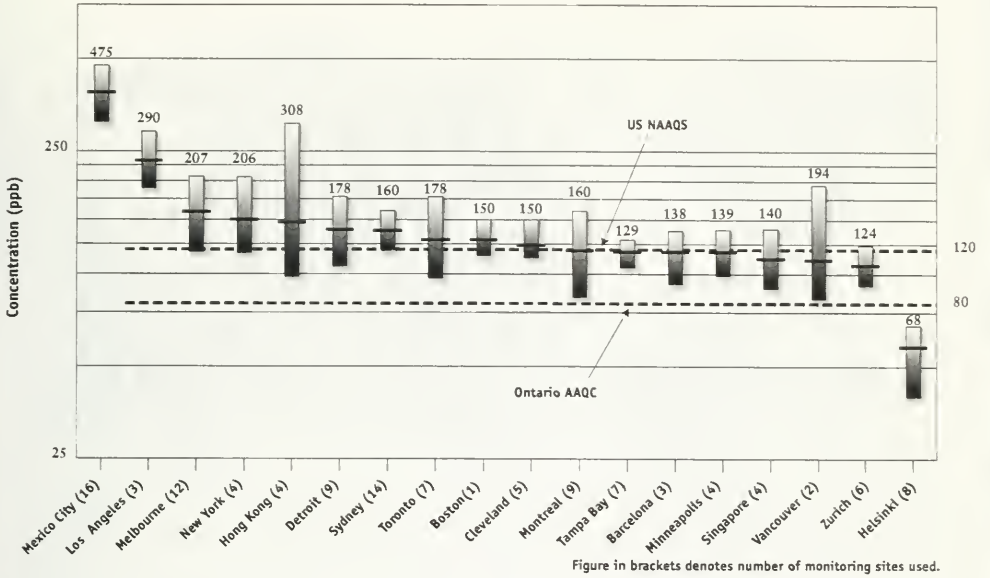


FIGURE 7.2
RANGE OF MAXIMUM ONE-HOUR OZONE LEVELS IN SELECTED WORLD CITIES 1988-1994



ozone levels for 1994 are displayed for 35 cities in **Figure 7.1.** The highest one-hour concentration during 1994 was recorded in Mexico City (312 ppb) followed by Los Angeles (250 ppb) and Bucharest (226 ppb). Of the 35 cities reporting, 20 exceeded the United States NAAQS (120 ppb) and 31 exceeded the Ontario AAQC (80 ppb). Of the 15 cities with populations above two million, Toronto recorded the lowest maximum value (103 ppb) during 1994. It should be noted that hourly values of ozone vary from year to year, depending on factors such as precursor emissions and weather.

The seven-year range in maximum one-hour ozone levels in 18 cities is shown in **Figure 7.2.** All cities except Helsinki recorded levels above the one-hour U.S. NAAQS and one-hour Ontario AAQC during these years.

PM_{10} RESULTS: Mean annual PM_{10} levels for 1994 are displayed for 27 world cities in **Figure 7.3.** The highest annual mean was recorded in Mexico City (239 $\mu g/m^3$), followed by Santiago (108 $\mu g/m^3$) and Kuala Lumpur (86 $\mu g/m^3$). Of the 27 cities reporting in 1994, eight exceeded the U.S. NAAQS 50 $\mu g/m^3$ and 15 exceeded the more restrictive California standard 30 $\mu g/m^3$. Toronto recorded the 20th highest PM_{10} annual mean. The seven-year range in annual mean PM_{10} levels in 17 cities is shown in **Figure 7.4.** Toronto was one of four locations which did not exceed either the annual U.S. NAAQS (50 $\mu g/m^3$) or the annual California standard (30 $\mu g/m^3$) during the seven years. Toronto PM_{10} levels were at the lower end of 17 cities reporting.

SO_2 RESULTS: The mean annual SO_2 levels for 1994 are shown for 30 cities in **Figure 7.5.** Only Mexico City exceeded the Ontario AAQC and, as expected, Toronto was at the lower end of annual means. Mexico City recorded SO_2 levels seven times higher than Toronto. The shift to cleaner burning fuels for heating and industrial purposes, and the Countdown Acid Rain program, have accounted for the low levels of SO_2.

NO_2 RESULTS: The mean annual NO_2 levels for 1994 are shown for 35 cities in **Figure 7.6.** Mexico City, Hong Kong, Rome and Milan were at the higher end of the annual means. Mexico City was the only location to exceed U.S. NAAQS. Toronto ranked 16th highest. Elevated NO_2 levels in the major cities are attributed primarily to motor vehicle emissions.

CO RESULTS: The one-hour maximum (23 cities) and eight-hour maximum (20 cities) CO concentrations are shown in **Figures 7.7** and **7.8** respectively, again for 1994. The one-hour U.S. NAAQS (35ppm) was exceeded only in Rome. The more restrictive one-hour Ontario AAQC

FIGURE 7.3
ANNUAL MEAN PM_{10} CONCENTRATION ($\mu g/m^3$) IN SELECTED WORLD CITIES FOR 1994

FIGURE 7.4
RANGE OF ANNUAL PM_{10} AVERAGES IN SELECTED WORLD CITIES 1988-1994

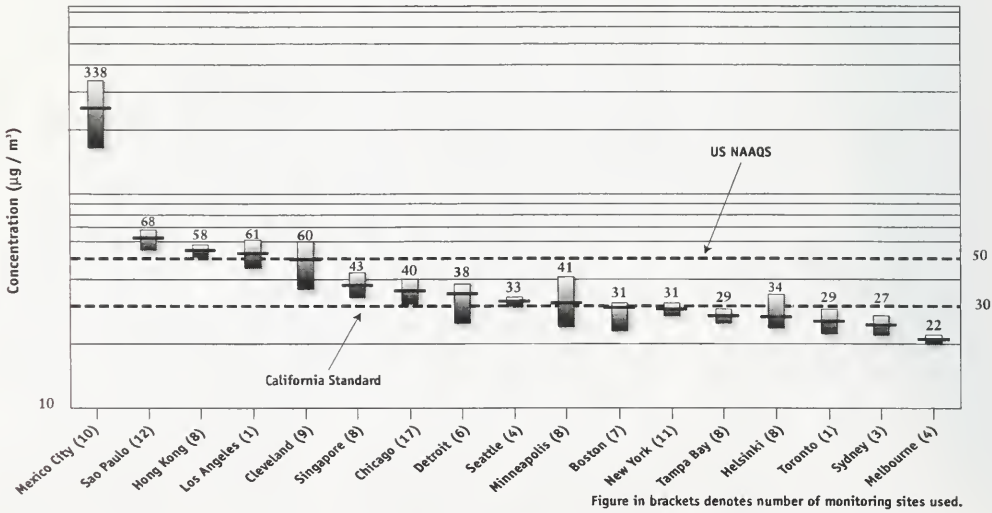


FIGURE 7.5
ANNUAL MEAN SULPHUR DIOXIDE CONCENTRATIONS IN SELECTED WORLD CITIES FOR 1994

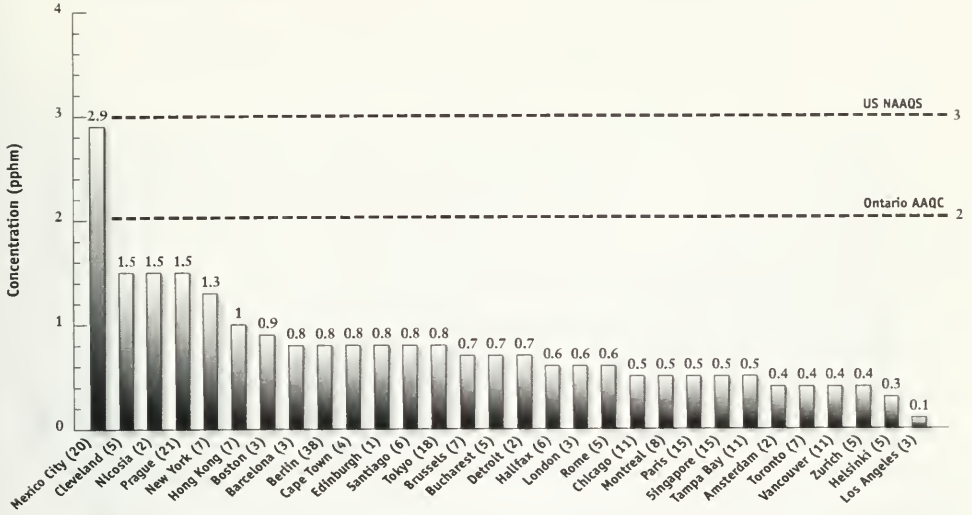


Figure in brackets denotes number of monitoring sites used

FIGURE 7.6
ANNUAL MEAN NITROGEN DIOXIDE LEVELS IN SELECTED WORLD CITIES FOR 1994

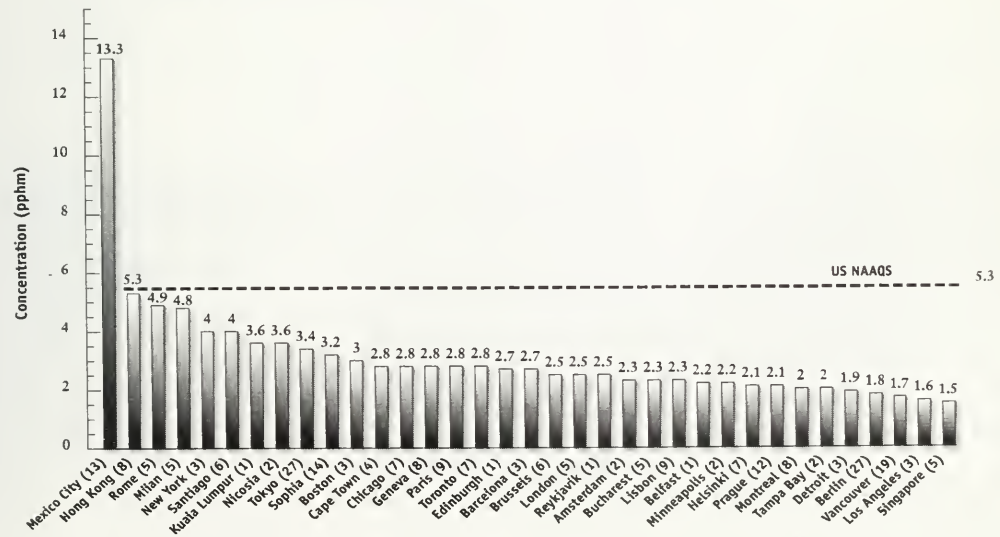


Figure in brackets denotes number of monitoring sites used

FIGURE 7.7
MAXIMUM ONE-HOUR CARBON MONOXIDE CONCENTRATIONS IN SELECTED WORLD CITIES FOR 1994

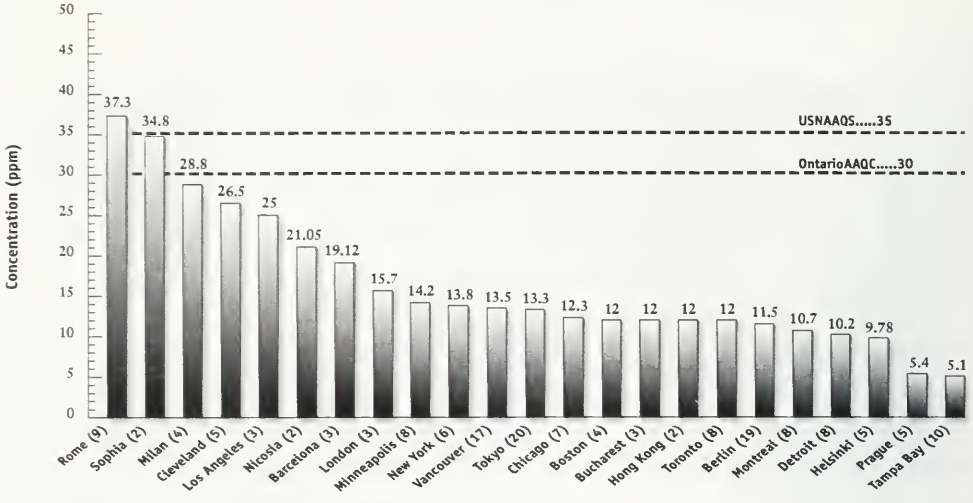


Figure in brackets denotes number of monitoring sites used

FIGURE 7.8
MAXIMUM EIGHT-HOUR CARBON MONOXIDE CONCENTRATIONS IN SELECTED WORLD CITIES FOR 1994

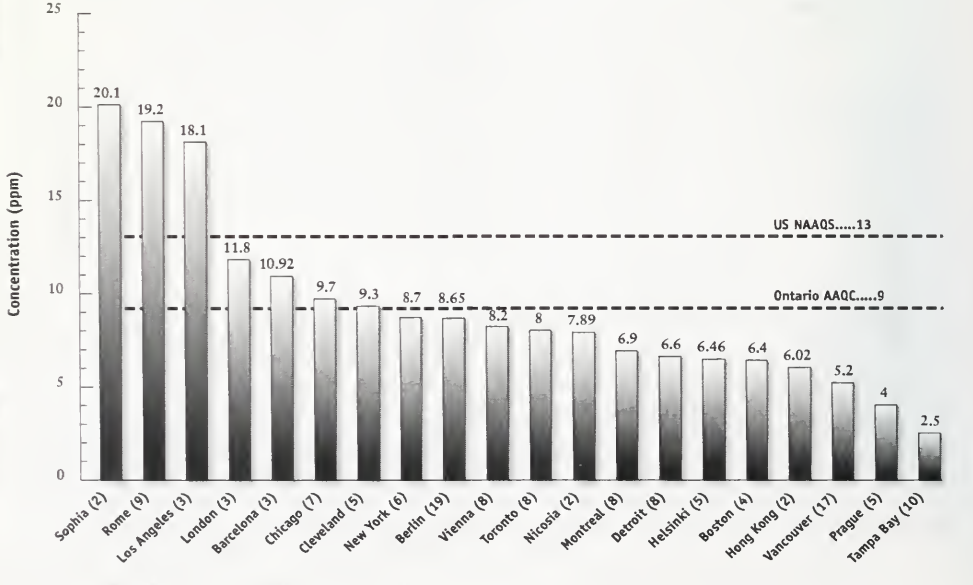


Figure in brackets denotes number of monitoring sites used

FIGURE 7.9
ANNUAL GEOMETRIC MEAN TSP CONCENTRATIONS IN SELECTED WORLD CITIES FOR 1994

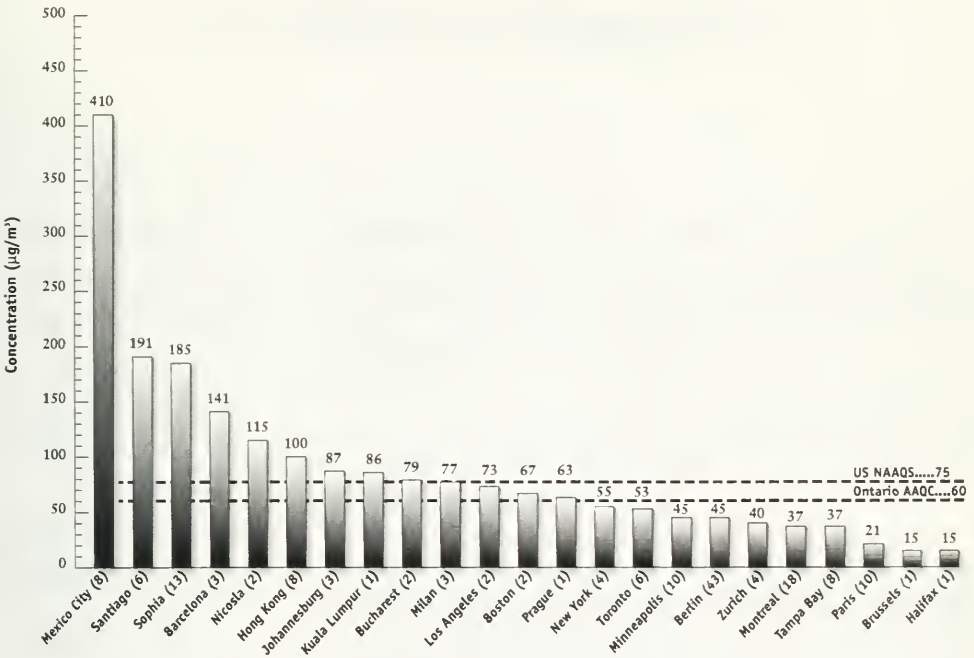


Figure in brackets denotes number of monitoring sites used

(30ppm) was exceeded in both Rome and Sophia. Elevated levels of CO in the major cities are largely attributed to vehicle emissions, local geography and weather. Several cities exceeded eight-hour U.S. NAAQS and Ontario AAQC. Metropolitan Toronto ranked 17th out of 23 cities for maximum one-hour CO concentration and 11th out of 20 for maximum eight-hour CO concentration. Toronto did not exceed either the U.S. or Ontario standards for CO.

TSP RESULTS: TSP is a good indicator of urban air pollution in large cities. It measures airborne particles with a diameter between 0.1 and 100 microns. Annual geometric means for 23 cities are shown in Figure 7.9. Several cities exceeded both the annual U.S. NAAQS and Ontario AAQC in 1994. Mexico City recorded TSP levels approximately eight times higher than Toronto. Toronto ranked 15th and did not exceed either U.S. or Ontario standards.

SUMMARY: The major objective of this study was to provide Ontarians with an international perspective on air quality levels in cities around the world. Vehicle emissions have a definite effect on air quality in major urban centres and will continue to do so because of continued economic and population growth.

Overall, Toronto's air quality during 1994 was better than many other major cities around the world. Toronto's air quality has steadily improved over the past 25 years as a result of various abatement programs.

CHAPTER 8

FUTURE DIRECTIONS

Significant decreases have been achieved for sulphur dioxide, carbon monoxide, total suspended particulates, nitrogen oxides and total reduced sulphur compounds.

MONITORING OVER THE PAST 25 YEARS HAS REVEALED A SIGNIFICANT DECLINE IN THE AMOUNTS OF COMMON POLLUTANTS IN ONTARIO'S AIR, WITH A CORRESPONDING IMPROVEMENT IN AIR QUALITY.

However, ozone, a secondary pollutant, remains a concern. Readings of ozone levels have been higher, on average, over the last seven years than in the previous decade. In 1995, air analysed at 41 of 45 ozone monitoring sites exceeded the one-hour Ontario ambient air quality criterion for ozone. It is estimated that more than 50 per cent of the ozone levels in Ontario are due to the long-range transport of ozone and its precursors from neighboring U.S. industrial states.

Because of the potential health and environmental effects of ground-level ozone, continued monitoring of ozone is required to evaluate trends and determine the effectiveness of reduction and abatement strategies.

The health and environmental effects of particulate matter (especially fine particles) is of growing concern. Numerous recent studies link fine particles, alone or in combination with other pollutants, with significant health problems. In response, Ontario has begun to change its existing monitoring network by deploying real-time monitors of inhalable and respirable particles (PM_{10} and $PM_{2.5}$). These are being phased in over the next few years. This strategy will allow improvements to the air quality index and air quality advisory programs by including fine particle measurements as a key element, along with ozone, in the air quality index network.

GLOSSARY AND ABBREVIATIONS

Acidic deposition - refers to deposition of a variety of acidic pollutants (acids or acid-forming substances such as sulphates and nitrates) on animal and plant life, on land or in the waters of the earth's surface.

Air quality index - real-time information system that provides the public with an indication of air quality in major cities across Ontario.

AQI station - air monitoring station in a built-up area, used to inform the public of air quality levels on a real-time basis; station must report on at least ozone and suspended particulates to be classified AQI.

Air pollution index - basis of Ontario's alert and control system to warn of deteriorating air quality; derived from 24-hour running averages of sulphur dioxide and suspended particulates.

Ambient air - outdoor or open air.

Carcinogenic - an agent which incites carcinoma (cancer) or other malignancy.

Continuous pollutant - contaminant for which a continuous record exists; effectively, pollutants which have hourly data (maximum 8760 values per year).

Continuous station	- where pollutants are measured on a real-time basis and data determined hourly (as for ozone, sulphur dioxide).
Criterion	- maximum concentration or level (based on potential effects) of contaminant which is desirable or considered acceptable in ambient air.
Daily pollutant	- contaminant with a 24-hour or daily value (maximum 365 values per year).
Detection limit	- minimum concentration of a compound contaminant that can be determined.
Gas chromatography	- separation technique involving passage of a gaseous phase through a column containing a fixed absorbent phase; used principally as a quantitative analytical technique for volatile compounds.
Geometric mean	- statistic of a data set calculated by taking the nth root of the product of all (n) values in a data set; provides a better indication than arithmetical mean of the central tendency for a small data set with extreme values.
Global warming	- long-term rise in the average temperature of the earth; principally due to an increase in the buildup of carbon dioxide and other gases.
Ground-level ozone	- colorless gas formed from chemical reactions between nitrogen oxide and hydrocarbons in the presence of sunlight near the earth's surface.
Inhalable particulate	- represents up to 60 per cent of total suspended particulate matter; composed of both primary (diameter 2.6 to 10.0 microns) and fine (diameter less than 2.5 microns) particles; also referred to as PM_{10}.
Landfill	- where regulated waste is placed in or on the land; waste disposal site.

Median	- the middle value of a set of numbers arranged in order of magnitude.
Monthly pollutant	- contaminant for which there exists only a monthly (30-day) value (maximum 12 values per year).
Ozone episode day	- a day on which widespread (hundreds of square kilometres of) elevated ozone levels (greater than 80 ppb maximum hourly concentration) occur simultaneously.
Particulate matter	- refers to any airborne finely divided solid or liquid material with a diameter smaller than 100 micrometres.
Photochemical oxidant	- any chemicals which enter into oxidation reactions in the presence of light or other radiant energy.
Photochemical reaction	- chemical reaction influenced or initiated by light, particularly ultraviolet light.
Photochemical smog	- see Smog.
Primary pollutant	- contaminant emitted directly to the atmosphere.
Respirable particles	- particles smaller than about 2.5 microns in diameter which arise mainly from condensation of hot vapors and chemically-driven gas to particle conversion processes; also referred to as $PM_{2.5}$. These are fine enough to penetrate deeply into the lungs and have the greatest health effects.
Secondary pollutant	- contaminant formed from other pollutants in the atmosphere.
Smog	- a contraction of smoke and fog; colloquial term used for photochemical fog, which includes ozone and other contaminants; tends to be a brownish haze.
Stratosphere	- atmosphere 10 to 40 kilometres above the earth's surface.

Stratospheric ozone	- ozone formed in the stratosphere from the conversion of oxygen molecules by solar radiation; ozone found there absorbs much ultraviolet radiation and prevents it reaching the earth.
Suspended particles	- suspended particulate most likely to reach the lungs (diameter less than 5-10 microns).
Total suspended particulate	- generic term for airborne particle including smoke, fume, dust, fly ash and pollen; approximately 0.1 to 100 microns in diameter.
Toxicity equivalent	- toxicity equivalent (TEQ) of chlorinated dibenzo-p-dioxins and chlorinated dibenzofurans calculated as follows: international toxicity equivalency factors (I-TEFs) are applied to 17 dioxin and furan isomers of concern to convert them into 2,3,7,8-TCDD (tetra chlorodibenzo-p-dioxin) toxicity equivalents; conversion involves multiplying concentration of the isomer by the appropriate I-TEF to yield the TEQ for this isomer; summing the individual TEQ values for each isomer of concern provides total toxicity equivalent level for the sample mixture. A table listing the 17 isomers of concern and their I-TEFs can be found in the ministry publication *Environment Information - Dioxin & Furans*; PIBS 681b, revised 08/91.
Troposphere	- atmospheric layer extending about 10 kilometres above the earth's surface.

Abbreviations

AAQC	- ambient air quality criterion
API	- air pollution index
AQI	- air quality index
AQUIS	- air quality information system
B[a]P	- benzo [a] pyrene
CO	- carbon monoxide
CO_2	- carbon dioxide
COH	- coefficient of haze reported as SP
EC	- Environment Canada
EMRB	- Environmental Monitoring and Reporting Branch
H_2S	- hydrogen sulphide
IP	- inhalable particulates
LIMA	- Lambton industry meteorological alert
MOEE	- Ministry of Environment and Energy
NAAQS	- national ambient air quality standard
NIST	- National Institute of Standards and Technology
NO	- nitric oxide
NO_2	- nitrogen dioxide
NO_x	- oxides of nitrogen
O_3	- ozone
OEIS	- Ontario emission inventory system
PAH	- polycyclic aromatic hydrocarbon
PCDD	- polychlorinated dibenzo dioxins
PCDF	- polychlorinated dibenzo furans
$PM_{2.5}$	- particulate matter less than 2.5 micrometres (microns) in diameter
PM_{10}	- particulate matter less than 10 microns
RP	- respirable particulate
SO_2	- sulphur dioxide
SO_x	- sulphur oxides
SP	- suspended particles
SVOCs	- semi-volatile organic compounds
TAGA	- trace atmospheric gas analyzer
TEQ	- toxicity equivalent
TRS	- total reduced sulphur
TSP	- total suspended particulates

USEPA	- United States Environmental Protection Agency
VOCs	- volatile organic compounds
WHO	- World Health Organization
$g/m^2/30$ day	- grams (of contaminant) per square metre per 30-day period
kg	- kilogram
kt	- kilotonne
$\mu g/m^3$	- microgram (of contaminant) per cubic metre (of air)
ng/m^3	- nanogram, i.e. one thousandth of a microgram (of contaminant) per cubic meter (of air)
pg/m^3	- picogram, i.e. one millionth of a microgram (of contaminant) per cubic metre (of air)
ppb	- parts (of contaminant) per billion (parts of air)
ppm	- parts (of contaminant) per million (parts of air)

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